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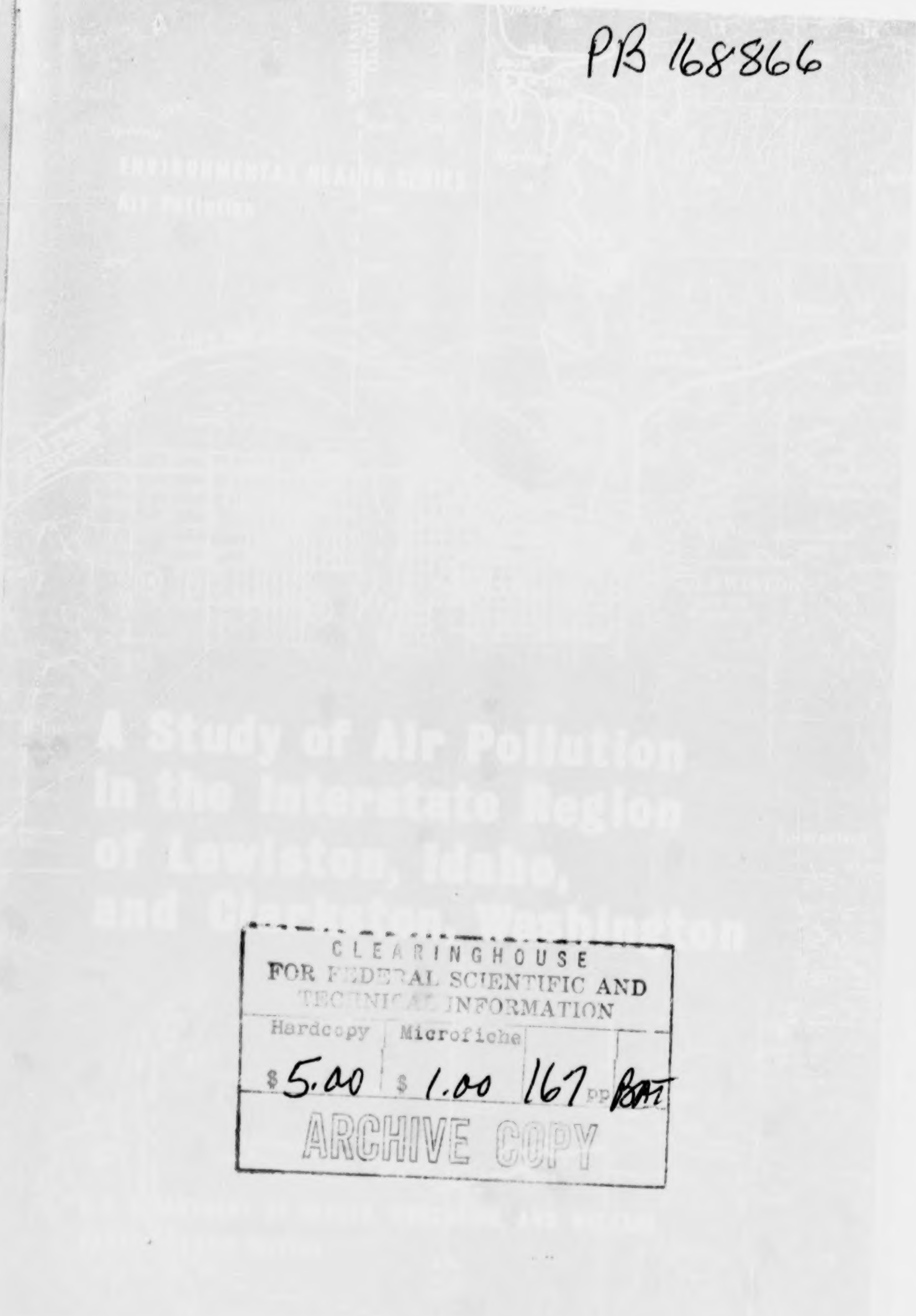

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Air Pollution

A Study of Air Pollution in the Interstate Region of Lewiston, Idaho, and Clarkston, Washington

AIR POLLUTION IN LEWISTON

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A STUDY OF AIR POLLUTION IN THE INTERSTATE REGION OF LEWISTON, IDAHO, AND CLARKSTON, WASHINGTON

PARTICIPATING AGENCIES

The City of Clarkston, Washington

The City of Lewiston, Idaho

Idaho Air Pollution Control Commission

North Central District Health Department, Idaho

State of Washington, Department of Health

Public Health Service, U.S. Department of Health,
Education, and Welfare

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

Division of Air Pollution

Cincinnati, Ohio 45226

December 1964

The ENVIRONMENTAL HEALTH SERIES of reports was established to report the results of scientific and engineering studies of man's environment: The community, whether urban, suburban, or rural, where he lives, works, and plays; the air, water, and earth he uses and re-uses; and the wastes he produces and must dispose of in a way that preserves these natural resources. This SERIES of reports provides for professional users a central source of information on the intramural research activities of Divisions and Centers within the Public Health Service, and on their cooperative activities with State and local agencies, research institutions, and industrial organizations. The general subject area of each report is indicated by the two letters that appear in the publication number; the indicators are

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Public Health Service Publication No. 999-AP-8

STATEMENT BY COOPERATING AGENCIES

This report is the product of cooperative efforts of the participating agencies. It represents an adequate description of the air pollution problems that motivated this study, and provides means to effect solutions to these problems in an equitable manner. The cooperating agencies agree that much still needs to be done to establish and implement an effective and reasonable air quality management program serving the best interests of the two communities and the two respective states.

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The Idaho Air Pollution Control Commission, in its letter of May 5, 1964, to the U.S. Public Health Service stated, "The Idaho Air Pollution Control Commission will be signatory to the report conditioned on a copy of this letter being inserted in the report after the signature page --." In accordance with this statement, said letter is reproduced below.

The inclusion of this letter does not constitute acceptance of nor agreement with statements made in the third paragraph of the Commission's letter by other agencies signatory to this report.

IDAHO AIR POLLUTION CONTROL COMMISSION
Statehouse
Boise, Idaho

May 5, 1964

Mr. Austin N. Heller, Chief
Technical Assistance Branch
Division of Air Pollution
U.S. Department of Health, Education and Welfare
Robert A. Taft Sanitary Engineering Center
Cincinnati 26, Ohio

Dear Sirs:

Concluding the hearing held this morning by the Idaho Air Pollution Control Commission called to consider your revised report entitled "A Study of Air Pollution in the Interstate Region of Lewiston, Idaho and Clarkston, Washington", the Commission directed me as its chairman to return the signature authorization, properly signed, for inclusion at Page ii, with the qualifications hereinafter expressed. *

The Idaho Air Pollution Control Commission wholeheartedly and unqualifiedly concurs in and endorses the recommendations contained at pages 8 and 9 of the report with respect to the establishment † of an air resource management council and pledges its support and cooperation in implementing the objectives of such council.

By directing me to be signatory to the report, the Idaho Air Pollution Control Commission, however, wanted it clearly understood that it does not approve the report in its entirety. There has been, in our considered judgment, a departure in the report from the objectivity with which we understood the problem would have been approached. In particular, the Commission feels that portions of the report covering (1) evaluation of air quality, (2) the odor survey, (3) the effects of air pollution, and, in particular, the health and welfare implications, are predicated on inadequate studies and investigation; and the conclusions therein reached are not supported on either a factual or a scientific basis.

The Idaho Air Pollution Control Commission will be signatory to the report conditioned on a copy of this letter being inserted in the report after the signature page ii, as page ii(a).

We do appreciate your revision of Exhibit B in accordance with our suggestions, and we approve the revised Exhibit B.

The Commission will leave the release of the report to your discretion, and we would be happy to provide a representative at any meeting called for that purpose.

Sincerely yours,

IDAHO AIR POLLUTION
CONTROL COMMISSION

By Jas. B. Hawley, Jr.
Chairman

JBH:ds

---

* Page iii of this report.

† Page 5 of this report.

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PREFACE

Recently, air pollution has been recognized as a major environmental problem because of the nuisance it creates, its damage to property and vegetation, and its effect on human health. The air pollution study in the Lewiston-Clarkston area of Idaho and Washington is a prime example of how joint efforts of federal, state, and city authorities can delineate the magnitude and extent of an air pollution problem involving more than one jurisdiction.

This joint study and report is the first necessary step towards improving the air environment for the people of this area. Its goal is to provide an understanding of the facts so that effective air resource management programs can be developed.

V. G. MacKenzie, Chief
Division of Air Pollution
U.S. Public Health Service

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ACKNOWLEDGMENTS

A survey of this size and scope, representing so many interests, is possible only through the cooperation of many individuals and organizations. Grateful appreciation is, therefore, extended to those whose generous giving of time, effort, and facilities made this study possible; to the individuals who aided in execution of the study and in preparation of the report; to the 240 students of the high schools in Lewiston and Clarkston who participated in the odor survey and the 6 instructors who supervised the work and daily transmitted the data. Without their help the survey could not have been accomplished. Our sincere thanks are directed to the Washington Water Power Company of Clarkston, Washington, which provided laboratory facilities, working space, and personnel to assist in the sampling program.

We acknowledge the contributions made by Robert Roland, Meteorologist in Charge, Weather Bureau Airport Station in Lewiston, Idaho; and by Keith Stokes, the City Engineer of Moscow, Idaho, who cooperated in locating and operating a control station there.

Finally, we express our sincere appreciation to the many residents of the two communities and their suburbs who gave freely of their time to supply information and other assistance.

ABSTRACT

As a result of an increasing number of complaints from citizens about reduced visibility, damage to house paint, tarnishing of silver, undesirable odors, and suspected effects of air pollution on health, Idaho and Washington and Lewiston and Clarkston officials requested assistance from the U. S. Public Health Service. Subsequently, the Public Health Service, the two states, and the two cities agreed to undertake a cooperative study; the two cities participated in the study. The purpose of the study was to determine the nature and extent of air pollution in the two-city area and to assemble information to be used as a basis for technical and official action needed to conserve air quality in the area.

Because of its unique valley location, the two-city area is susceptible to meteorological conditions conducive to pollutant accumulation. Either city can contaminate the other, and this creates a multijurisdictional problem that requires joint and cooperative action to control air pollution. As a first step to solve the problem, an Air Resources Management Council consisting of county, city, and state officials is to be organized. This council will be responsible for planning surveys and studies to determine air quality guides and legislation and administration necessary to control air pollution in this multijurisdictional area. The Public Health Service in its advisory capacity will provide technical assistance.

SUMMARY

To comply with a request for assistance from officials of the City of Clarkston, a cooperative interstate study of air pollution was conducted in the communities of Lewiston, Idaho, and Clarkston, Washington, during the winter of 1961-1962. The request was motivated by public complaints about reduced visibility, damage to house paint, tarnishing of silver, undesirable odors, and suspected effects on health resulting from air pollution. The kraft pulp mill located near Lewiston about 2 miles east of Clarkston was cited as a major source of pollution.

The purpose of the joint study was to determine the nature and extent of air pollution in the two communities, and to assemble data and information needed as a basis for remedial action. The study included the following activities:

1. Analysis of past and current data on meteorology.
2. An emission inventory.
3. Measurement of atmospheric pollutants.
4. Measurement of visibility.
5. Assessment of ambient odors.
6. Measurement of materials deterioration.
7. Interview of local physicians concerning health effects.
8. A survey of public opinion.

The meteorological studies included a review of past climatological and meteorological data, and observations of wind speed, wind direction, temperature, and relative humidity at a station in the valley to supplement concurrent data collected at the Lewiston airport.

The two communities are in a deep, narrow valley at the confluence of the Snake and Clearwater Rivers. The climate is relatively mild, compared with other sections of Idaho, but the cities frequently experience poor atmospheric ventilation owing to low wind speed and low-level inversions. Actually, Lewiston seems to have the lowest average annual wind speed of any city for which Weather Bureau records are available. The predominant wind direction is from the east, particularly at night. Stationary high-pressure systems conducive to air pollution and lasting several days can be expected twice yearly. Low-level inversions are most frequent in the fall, when they may be expected to occur about 50 percent of the time.

Meteorological measurements during the sampling period showed wind speeds higher and frequency of easterly winds lower than normal. These factors tended to remove pollution from the area.

An estimate of major air contaminant emissions for the area was made from information provided by the communities and industries in the area. No stack sampling was done, and all estimates were based on information from the literature and other sources.

The major contributor of hydrogen sulfide and other malodorous organic gases is the kraft pulp mill. In addition, the pulp mill contributes about 77 percent of the estimated gaseous emissions and about 82 percent of the estimated particulate emissions. It also contributes an estimated 4,640 tons of water vapor each day to the atmosphere. This is thought to have a significant effect on the humidity in the valley under certain meteorological conditions. The major gaseous emission from the pulp mill is the "combustible" from three recovery furnaces and three lime kilns. This combustible probably consists of carbon monoxide and partially oxidized organic compounds.

The pulp mill has installed many control devices, but the recovery furnaces and kilns may, from time to time, emit odorous compounds to the atmosphere. A sulfate pulp mill also has innumerable small sources of odor emission that in total constitute a difficult problem.

Emissions from other industrial operations are relatively small. Home heating is the largest source of sulfur oxides, and transportation (gasoline engine exhaust) contributes a substantial amount of carbon monoxide to the atmosphere. Refuse disposal is a relatively minor source of air contamination on a weight basis, but the odor produced by burning garbage and refuse causes a local nuisance.

The evaluation of air quality included measurement of ambient concentrations of hydrogen sulfide, sulfur dioxide, and suspended particulate matter at five sampling stations in the Lewiston-Clarkston area, and a control station in Moscow, Idaho. Paint and silver specimens were exposed to measure deterioration caused by hydrogen sulfide and other sulfide compounds. Visual and photographic observations were used to measure visibility reduction. Odor surveys were conducted in the two communities in November and April.

Data on suspended particulate matter revealed both natural and industrial sources of pollution. Sulfate and sodium contents of the suspended particulates were significantly higher in the Lewiston-Clarkston area than in Moscow, Idaho, a nearby non-industrial city of comparable size.

Visibility reduction data, correlated with meteorological data, and data on humidity and emissions of water vapor from the mill indicate that a visibility problem exists. The presence of smoke most often resulted from a combination of stable atmosphere with high relative humidity and an easterly wind.

Hydrogen sulfide levels were significantly higher at sampling sites in the valley. Concentrations were highest in November and February, which were periods of higher frequency of inversions. Hydrogen sulfide levels in Moscow were consistently low and showed no diurnal variation. Significant morning peaks occurred between 8 and 10 a.m. at the two Clarkston stations, and between 10 and 12 noon in the Lewiston commercial area. The time difference is due to the unique topography of the study area. Two stagnant weather episodes, lasting 8

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and 10 hours, were observed in which hydrogen sulfide concentrations exceeded 10 parts per billion.

Atmospheric sulfur dioxide was measured continuously over 2-week periods in each of the months, November, January, and April. A total of 512 2-hour samples were collected. The concentration range was highest in January (range 0-25 ppb, average 4.7 ppb) during the coldest period, indicating fuel burning for space heating as the primary source of sulfur dioxide. Maximum daily concentrations occurred at 9 a.m., at the time of inversion breakup. Atmospheric contamination by SO_2 is not currently a problem.

Odor surveys were made in November and in April with an observer corps of approximately 100 high school students from the two communities to determine odor types, intensities, and possible sources. The students were first given odor sensitivity tests. Odor observations were made three times daily at prescribed times. Each observer reported any odor experienced and an estimate of its intensity. The analyzed data show that pulp mill odors represent the largest single nuisance odor category, affecting Lewiston most in November and Clarkston most in April. The number of reports of burning leaves did not vary significantly between areas. Odors of open trash burning were reported frequently in the Clarkston area in November, indicating a localized problem. Pulp mill odors were reported most frequently in the morning. Odors from the burning of wood, leaves, and rubbish were reported more frequently in the afternoon. There was no significant difference between the two periods based on response to all odor types. Pulp mill odors varied between November and April in the Lewiston area.

Materials deterioration studies were conducted to show effects of polluted air on white lead-based house paint and on silver plate. Paint panels and silver plates were exposed on a scheduled basis during the 6-month study period and evaluated for deterioration by measurements of the decrease in reflectance. Silver plates were also exposed at a control station in Moscow, Idaho. Data from these tests showed negligible silver tarnishing in Moscow. Silver plates exposed in the valley were tarnished more than those exposed in the upland sites. New plates were tarnished more during the first 30 days of exposure than in the later part of the study. Lower levels of tarnish during December and January correlate with lower levels of air pollution during this period. The relative severity of tarnishing, as an indicator of sulfide gases in the air, is greater in Lewiston than in Clarkston. The results obtained from exposed paint samples were inconclusive.

Studies to provide precise data relating to health effects and pollutant concentration were not made. Information obtained through interviews of local physicians revealed that many believed local air pollution was adversely affecting some of the townspeople.

The survey of public opinion concerning air pollution, conducted in Clarkston during May 20-25, 1962, showed that approximately 81 percent of the 104 persons interviewed believed that Clarkston had an air pollution problem. About 66 percent indicated they were bothered by it. Bad smells, frequent haze or smog, nose and throat irritation, eye irritation, excessive dust and dirt were cited as the principal air pollution phenomena. More than 90 percent of the respondents who reported they were aware of air pollution named the pulp mill as responsible. More than 33 percent of the people feel the need for official enactment of air pollution control measures. Air pollution in Clarkston appears to constitute a community-wide problem. Concern appears to be associated with civic pride and a desire to ameliorate the situation.

The study demonstrates the need for establishing a Regional Air Resource Management Council and for establishing air quality goals, as well as a program for air quality monitoring, for predicting adverse episodes, and for controlling sources of pollution, such as the garbage dump and specific factory emissions. The council would consist of representatives designated by city, county, and state governments as well as commercial and industrial establishments.

A program of action calls for the use of every opportunity to resolve air pollution problems without resort to legal redress so long as reasonable progress is evident as determined by the control council.

RECOMMENDATIONS *

In making these recommendations, the participating agencies recognize that the protection of air resources is essential to human well-being and orderly development of the area. Accordingly, it is recommended that:

1. An Air Resource Management Council should be organized and activated in 1964. The Council would consist of representatives from appropriate county and municipal agencies and from each of the respective state governments. The Public Health Service would act in an advisory capacity.

2. The Council should develop a program that might include the following:

    (a) Establish an air quality monitoring network, including meteorological instrumentation.

    (b) Assist in the development of a plan to control emissions of air pollutants at the sources.

    (c) Arrange for personnel and other resources needed to implement the program.

    (d) Determine the need for additional studies and arrange for their implementation.

The manner, method, and time scheduled for accomplishing these goals will be decided by local and state officials with the guidance of the public and representatives of commercial and industrial interests of the area.

3. The Council should release annual reports to permit evaluation of progress and to engender continued support.

4. Every opportunity should be given to resolve air pollution problems in the area without resort to legal redress so long as reasonable progress is evident as determined by the Council.

5. Local, city, and county governments should take steps to minimize the air pollution problem from the burning of refuse by individuals. Further, the City of Clarkston should eliminate the open burning of municipal refuse.

---

* Agreed to by the participating Agencies at the conference held in Coeur d'Alene, Idaho, July 6-10, 1963.

CHAPTER I. INTRODUCTION

DESCRIPTION OF THE STUDY AREA

This report explores an air pollution situation unique in many respects. A narrow, deep river valley impedes nature's attempts to disperse and dilute emissions to the atmosphere. Interstate transport of emissions occurs.

The twin cities of Lewiston and Clarkston are a major center of commerce and trading for a population of over 100,000. Lewiston, Idaho's first territorial capitol, now has a population of about 12,700. Lewiston Orchards, unincorporated, adds approximately 10,000 to the area. Clarkston has a population of about 7,000, with Clarkston Heights adding more. Thus, about 30,000 people reside in the valley area.

The cities are located at the confluence of the Snake and Clearwater Rivers at 738 feet above sea level, about 110 miles southeast of Spokane, Washington. The area is set in a rather narrow valley oriented east and west with a range of hills on the north sloping abruptly to about 2,000 feet above the valley floor. To the south the terrain rises more gradually to a flat bench about 700 feet above the valley.

This area, at the lowest elevation in Idaho, has a very mild climate, from which it gets its name, "the Banana Belt." Rainfall averages 13 inches annually. On the prairies surrounding the valley, winter temperatures generally are much lower and precipitation almost double that recorded in the valley.

The mildness of the winters, the long growing season, and the good soil combine to make the area an important agricultural center. Wheat is the principal crop, but near the cities abundant fruit and vegetable crops are grown under irrigation. The biggest single business is making forest products. Each of the cities has three or four lumber mills. Lewiston is the home of Potlatch Forests, Inc., reputedly one of the largest white pine pulp mills in the world. It is estimated that one-third of the area's labor force is employed directly by this plant, and another large portion of the population is indirectly dependent on the mill.

The cities are preparing for a day when deep-draft barges will tie up at their docks to carry the resources of North Central Idaho down the Snake and Columbia Rivers to the markets of the world. Dams under planning and construction on the lower Snake River soon will make this a reality. The completion of the Lewis-Clark Highway also linking the Pacific Coast with the area and opening opportunities for travel and resources development to the east through Montana will spur the growth of the area. Already new industrial sites are being recommended for plants of all kinds.

With growth have come air pollution problems and with further growth will come additional problems unless steps are taken now to initiate sound air resource management programs. Complaints of the local citizens have increased in recent years. They cite the pulp and paper mill in the Lewiston area as responsible for reduced visibility, damage to house paint, tarnishing of silver products, undesirable odors, and suspected effects on health. The mill owners have recognized their responsibility to the communities and have attempted to be good neighbors by spending thousands of dollars to reduce and prevent pollution. Nevertheless, complaints continued and steps were taken by the local citizens to obtain help in improving air quality.

DEVELOPMENTS LEADING TO THE STUDY

On November 4, 1960, Mr. Bill V. Courtney, then Mayor of Clarkston, wrote to Mr. Vernon G. MacKenzie, Chief, Division of Air Pollution, Public Health Service, requesting assistance in resolving an air pollution problem affecting both the Clarkston, Washington, and Lewiston, Idaho, areas. The major source of air pollution was said to be the pulp mill operated by Potlatch Forests, Inc., near Lewiston and about 2 miles east of Clarkston.

In response, the Public Health Service, through its regional offices, communicated with the appropriate departments of the two state governments. The purpose of this communication was to assemble available information regarding the extent of the air pollution problem and to determine what, if any, activities were intended for its solution. The Public Health Service also offered to send an engineer from the Division of Air Pollution to meet with the appropriate officials of each state.

At the request of the Idaho Air Pollution Control Commission, Mr. J. J. Scheuneman, Chief, Technical Assistance Branch, met with officials of the Commission and the Idaho State Department of Health in Boise on June 5, 1961. It was agreed that the Public Health Service would prepare a draft of a proposal describing the air pollution studies to be conducted on a cooperative basis with the Idaho Air Pollution Control Commission, the Idaho State Department of Health, and the local agencies in the Lewiston area.

A subsequent meeting was held with officials of the Washington State Department of Health, and a similar agreement was reached.

On August 15, 1961, proposals were submitted to officials in both Idaho and Washington for a cooperative air pollution study to be started in October 1961. As the various agencies agreed to proceed with the study program, meetings were subsequently held in Lewiston, Idaho, during the week of October 16. All the agencies concerned were represented, and details of the program were reviewed. Agreement was reached to start the studies during the week of October 23.

PURPOSE AND SCOPE OF THE STUDY

In view of the apparent official and public concern about air pollution in the area and the complex jurisdiction needed to resolve the problems, the Division of Air Pollution of the Public Health Service entered into an agreement with the states of Idaho and Washington and the cities of Lewiston and Clarkston to conduct a cooperative study to determine the nature and extent of the air pollution and collect data and information as a basis for technical and official action.

The survey was initiated during the week of October 23, 1961, with the following general objectives:

1. To estimate the nature, extent, and effects of air pollution in the area.

2. To sample the opinion of persons living in Lewiston and Clarkston to determine: (1) the proportion of the population disturbed by air pollution, (2) their geographic distribution, and (3) the source and severity of the problem.

3. To recommend practical and reasonable measures for control of air pollution in the area.

THE TECHNICAL STUDIES PROGRAM

The joint air pollution studies included the following major activities, each of which is discussed in detail in this report:

1. Meteorological observations were made of wind speed, wind direction, temperature, and relative humidity at a station located in the valley to supplement concurrent data collected at the U. S. Weather Bureau Station at the Lewiston airport. The data were used to evaluate the air pollution potential of the area, to establish the normality of the sampling period, and to interpret more objectively the air quality data obtained from the study.

2. An emission inventory of all major sources of pollution in the area gave estimates of the quality and quantity of contaminants discharged into the ambient air from the various sources. Although no stack sampling was conducted, emissions from domestic, commercial, and industrial sources were calculated from available data.

3. Analyses of air samples for hydrogen sulfide, sulfur dioxide, suspended particulate matter, sodium, calcium, and sulfate revealed the frequency of occurrence and the severity of pollution levels. Correlations of air quality data with observa-

tions of weather and odor levels substantiated the findings of the emission inventory regarding the major pollutants and their sources.

4. Visibility reduction in the valley was studied by use of photographs, visibility observations, and evaluation of relative humidity data with concomitant smoke observations by U. S. Weather Bureau personnel.

5. Odor surveys carried out for 2 weeks each in November and April determined the odor intensities, types, and probable sources. Odors were evaluated by use of scentometers and by use of high school student observers.

6. To determine the effect of atmospheric pollutants on paint and silver, sample specimens were exposed and compared with similar samples exposed in Moscow, Idaho. Laboratory tests confirmed the presence of sulfides on the exposed surfaces of silver plates.

7. A public opinion survey conducted in Clarkston reflected the adult population's views concerning local air pollution, its sources, severity, effects, and the means for control.

During this investigation the U. S. Public Health Service provided technical equipment, supplies, and manpower. The States of Idaho and Washington provided supplies and manpower; local agencies and other personnel did much of the sample collecting and periodic equipment servicing. The field aspects of the survey were concluded April 30, 1962. The preparation of an initial draft of this report was assigned to the Public Health Service. Subsequent detailed comments by all participating agents were incorporated, and are reflected in this final joint report.

SUMMARY

To comply with the requests for assistance from city and state officials, the U. S. Public Health Service entered into an agreement with the States of Idaho and Washington and the cities of Lewiston, Idaho, and Clarkston, Washington, to conduct a cooperative study of air pollution in the Lewiston-Clarkston area. The Cities of Lewiston and Clarkston participated in the project. The request was motivated by an increasing number of complaints from citizens about reduced visibility, damage to house paint, tarnishing of silver, undesirable odors, and suspected effects of air pollution on health. The kraft pulp mill, located near Lewiston and about 2 miles east of Clarkston, was cited as a major source of pollution.

The purpose of the joint study was to determine the nature and extent of air pollution in the two-city area, and to assemble data and information as a basis for technical and official action needed to conserve air quality. The joint air pollution studies conducted November 1961 through April 1962 included the following major activities:

1. Analyses of past and current data on meteorology.
2. An emission inventory.
3. Measurement of atmospheric pollutants.
4. Measurement of visibility.
5. An odor survey.
6. Materials deterioration studies.
7. A public opinion survey.

CHAPTER II. AIR POLLUTION POTENTIAL - METEOROLOGY

TOPOGRAPHY

Lewiston and Clarkston are in a Y-shaped valley where the Snake River, flowing from the south, turns abruptly to the west and is joined by the Clearwater River flowing from the east (Figure 2-1). The east-to-west portion of the valley is rather narrow, with a range of foothills to the north sloping abruptly to about 2,000 feet above the river, which at the city of Lewiston is about 700 feet above mean sea level. To the south the terrain rises more gradually to a relatively flat bench, which is east of the Snake River and about 700 feet above the valley floor.

CLIMATOLOGY

Temperature [1]

Although Lewiston is at about the same latitude as Duluth, Minnesota, the climate, especially in winter, is comparatively mild, which is explained by its location with respect to Pacific air masses and by the shelter provided by surrounding mountains.

Within relatively short distances from the valley, however, the climate varies considerably. On the prairies surrounding the valley, winter temperatures are much lower, and the precipitation is normally almost double that recorded in the valley and at the airport.

Temperatures range from the highest recorded, 117°F, to the lowest, -23°F, but during many winters a temperature of zero has not been recorded in the valley. The summers are hot and dry with afternoon temperatures of 100° or more continuing for as many as 10 days, but there is considerable cooling after sunset.

The amount of pollution resulting from space heating is inversely related to temperature. A commonly used measure of heating requirements is the degree-day value found by subtracting the mean daily

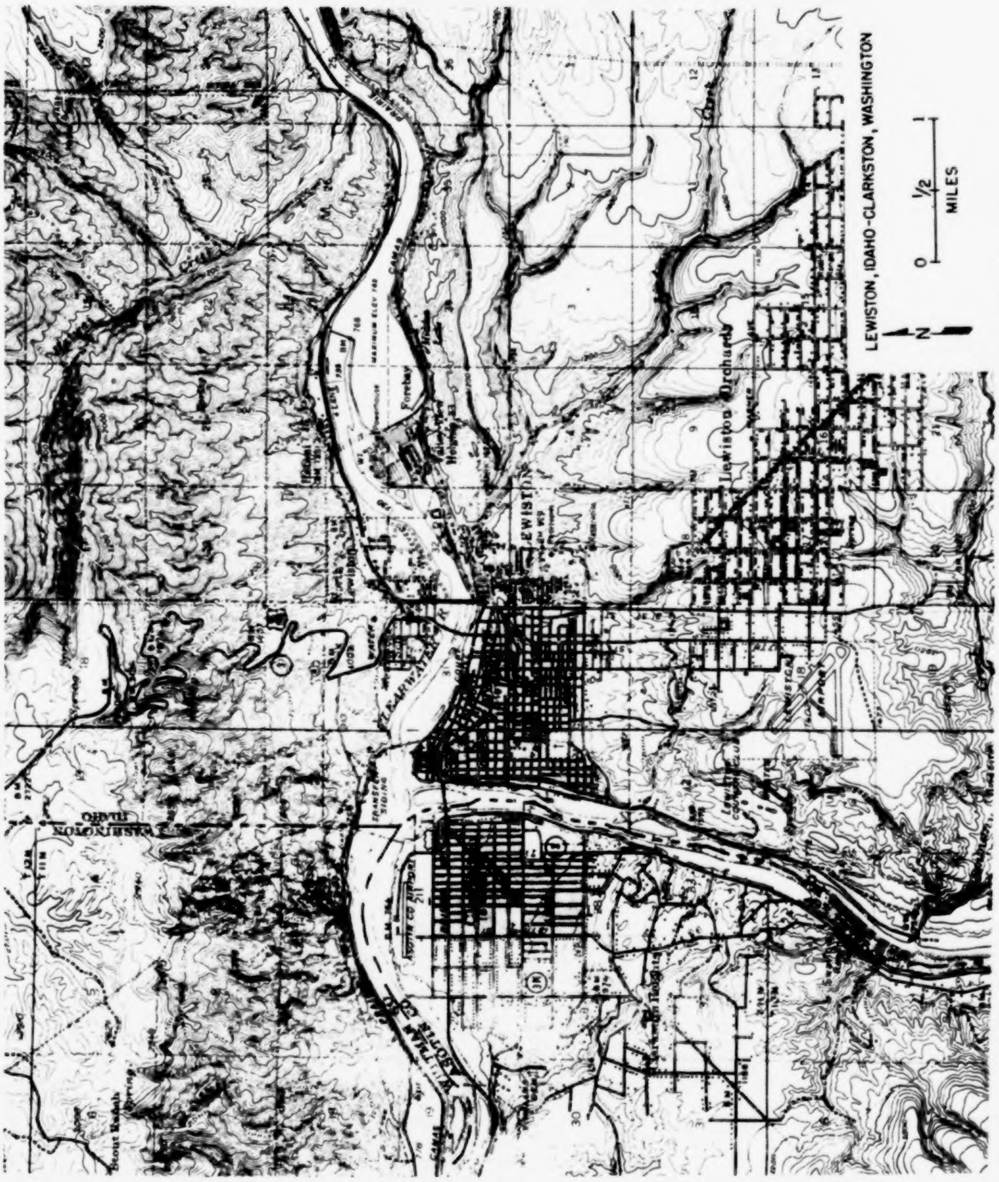
LEWISTON, IDAHO-CLARKSTON, WASHINGTON
N
0
1/2
1
MILES
LEWISTON
Lewiston Orchards

Figure 2-1. Topographic map of Lewiston, Idaho, and Clarkston, Washington, area.

temperature in degrees from 65°F. If the mean temperature is 65°or greater the degree-day value is 0. For example, if on a day, the maximum temperature is 49° and the minimum is 31°, giving a mean of 40°, the degree-day value is 25. These values are summed over each month of the heating season. The normal monthly degree-day values based on 30 years of data are shown in Figure 2-2, which indicates that the heating season extends from September into June with heating requirements for December and January about 2.5 times those for October and April.

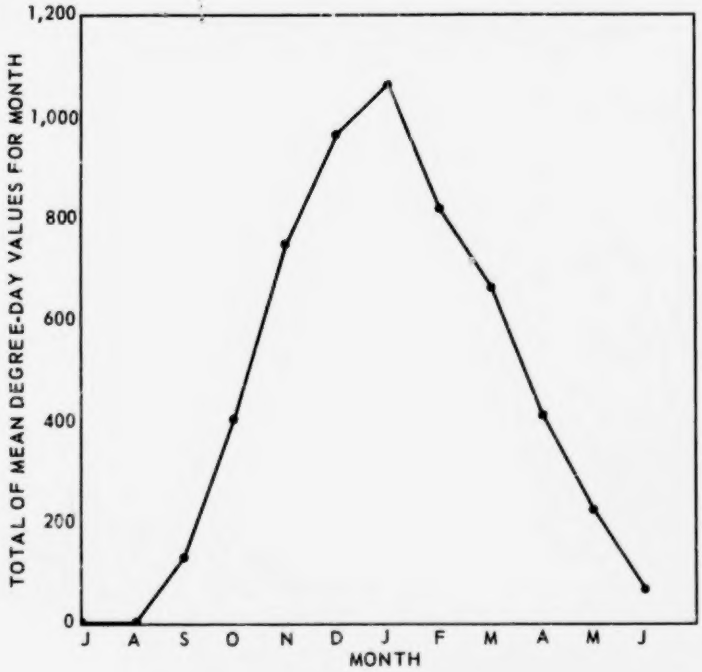

Figure 2-2. Normal heating requirements for the Lewiston–Clarkston area.

PRECIPITATION

Although precipitation is of minor importance in an assessment of the air pollution potential of an area, it does remove air pollutants, especially larger particulates, by washout.

For the study area precipitation usually amounts to about 13 inches annually, evenly distributed, except for July and August, when there are infrequent thunderstorms that usually drop only small amounts of rain. Snowfall in the valley averages about 18 inches during the year, concentrated in December, January, and February, but in the high country surrounding the valley the snowfall is much heavier.

WIND

Of perhaps the greatest importance to an assessment of the air pollution potential of an area is the pattern of its winds, since the winds transport pollutants from their sources and dilute them to lower concentrations. If reversals of flow occur, pollutants emitted from a source may return to the vicinity of the source and result in increased concentrations. Pollution is diluted downwind in direct proportion to the wind speed. Low wind speeds that allow high pollutant concentrations are, therefore, of special interest. Wind speeds and directions are influenced greatly by topography and may be expected to differ at different locations. To evaluate the winds in the study area, a comparison of 5 years of record at the airport (1957-1961) with 5 years of record at the Post Office Building in downtown Lewiston (Dec. 1927 - Nov. 1932) was made for the four seasons at the hours 0400, 1000, 1500, and 1900. Simultaneous observations are not available since the Post Office Station was closed in 1933. The airport is about 2 miles south of Lewiston and 700 feet above the business section of the City. The wind roses are shown in Figure 2-3.

Wind Speed

Figure 2-4, comparing the percent frequencies of winds between 0 and 3 mph for both locations, shows that the city location definitely has a higher frequency of low winds and so cannot disperse pollutants as effectively as the location near the top of the valley. Variation of the speed frequencies with respect to time of day is greatest during summer and least in winter. Low wind speeds are most frequent during fall at the city location and during winter at the airport. Light winds are generally most frequent at the hours 0400 and 1900 at both locations and least frequent at 1500. The airport reported a much higher frequency of calms. This resulted primarily from differences in the types of instruments and the observational procedures; total miles of wind passing each hour were recorded in 1927-1932 whereas 5-minute average winds were read from an indicating dial for the 1957-1961 observations. In an attempt to eliminate the effects of these differences, only the frequencies of winds from 0 to 3 mph have been compared.

Wind Direction

Wind direction varies considerably at various times of the day at both locations. At 0400 at the airport, for all seasons, winds from the east and southeast dominate. This probably results from a combination of downvalley (easterly component) and downslope (southerly drainage components) effects. Winds at this same time in the city are also primarily easterly (downvalley), but have a secondary prominence of northeasterly winds rather than southeasterly, especially in winter. This is probably the result of downslope effects (northerly component) from the north side of the valley, which is much higher and steeper than

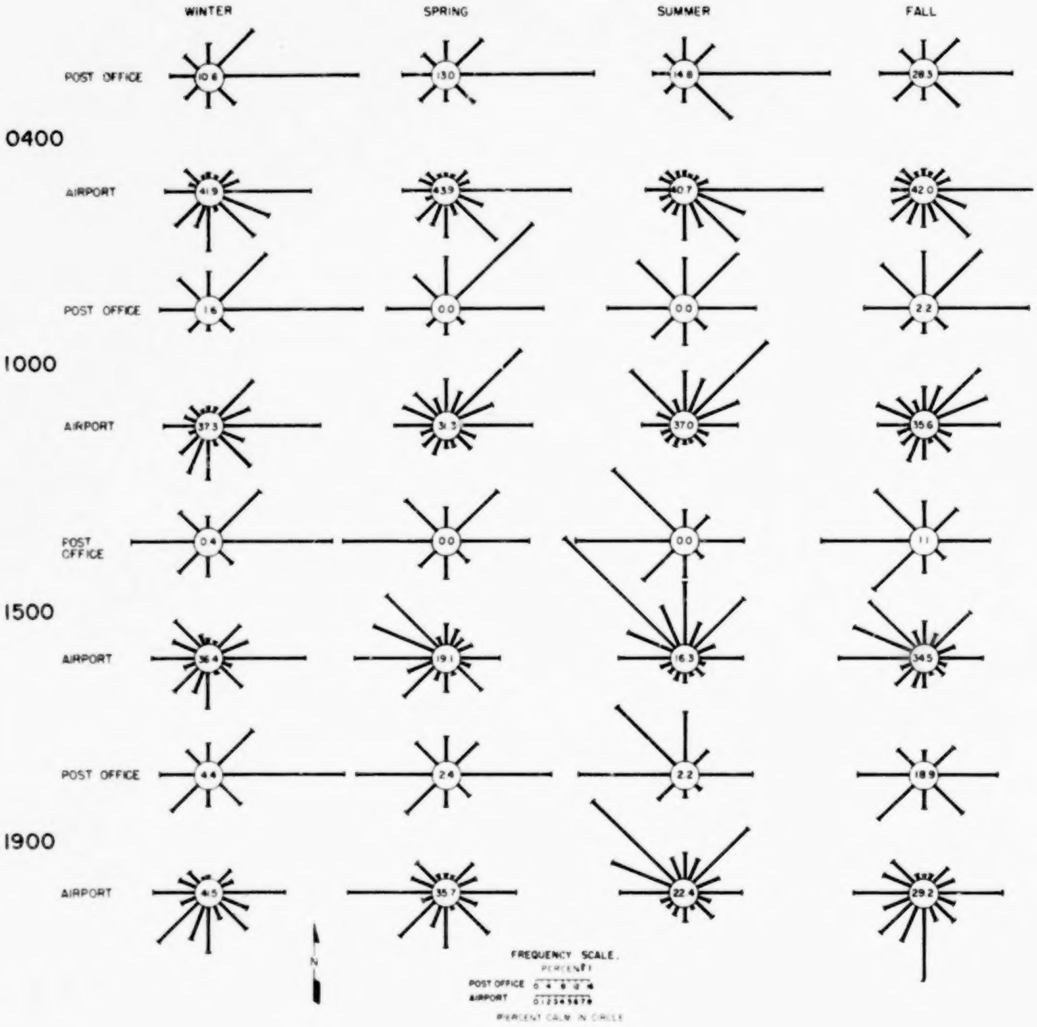

Figure 2-3. Wind direction frequencies, Lewiston, Idaho, based on 5 years of record – Post Office Dec. 1927-Nov. 1932; Airport Jan. 1957-Dec. 1961.

the south side of the valley and would be expected, therefore, to develop a stronger slope wind.

At 1000 at the airport, the predominant winds come from the northeast except in winter, when flow is predominantly easterly. This probably results from the combined effects of the beginning of upslope winds (from the north) and the downvalley winds remaining from the night. In the summer, secondary maxima from the northwest and north occur indicating enough heating by 1000 in this season for an upvalley component to begin. At this same hour in the city, flow is from the east and northeast; probably a continuation of nighttime conditions. In the summer more westerly and northwesterly winds occur as at the airport, an indication of the beginning of upvalley flow during the warmest season.

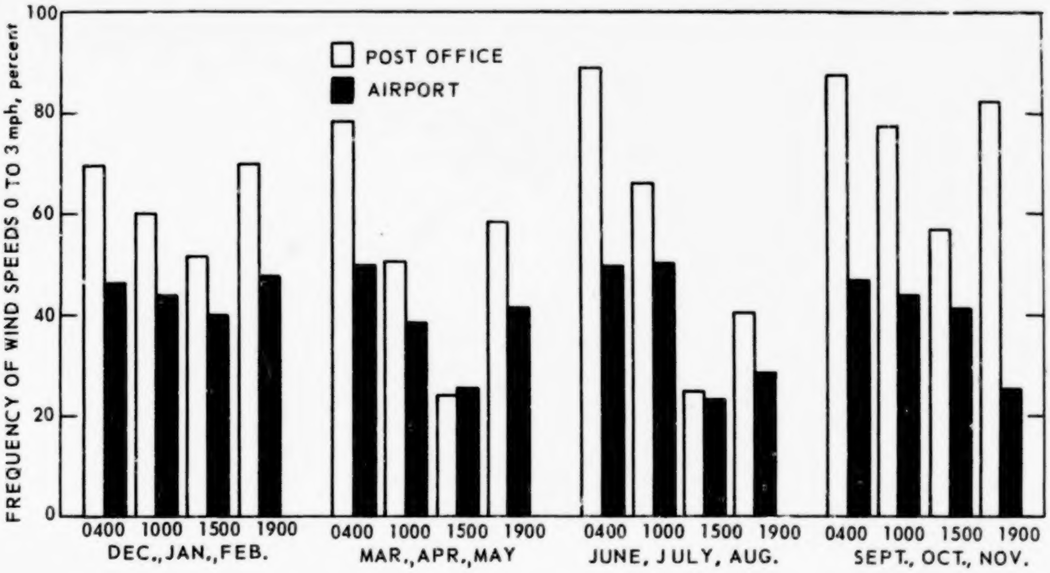

Figure 2-4. Frequency of wind speeds from 0 to 3 mph for selected hours in Lewiston, Idaho. Based on 5 years of record: Post Office, Dec. 1927 - Nov. 1932; Airport, Jan. 1957 - Dec. 1961.

At 1500 at the airport, in all seasons except winter, predominant winds are from the west and northwest, indicating upslope and upvalley components. In the winter there is not sufficient solar heating to produce upvalley and upslope winds. Frontal passages are also most frequent in winter. Winter winds at 1500 are slightly more easterly with a lack of northerly winds and about equal distribution through the west and south quadrants. The city location also has high frequencies of west and northwest winds at 1500 during all seasons except winter. During summer and fall some southwesterly winds also occur at this hour, owing, perhaps, to upslope winds on the north slope of the side of the valley caused by domination of circulation by strong solar heating.

At 1900 at both locations, upslope and upvalley winds still occur in summer, which results in dominant northwesterly winds. In the other three seasons winds from south through west generally predominate, probably because of the combination of the onset of downslope winds with the last of the upvalley flow. This southwesterly flow is least in winter, since an upvalley flow from the west is never too strongly established in winter. Spring and fall show almost a balance between west and southwest winds and east and northeast winds, which indicates, perhaps, the onset of downslope winds from the north slope and downvalley drainage winds at least part of the time. Winter is dominated by easterly winds with a secondary maximum at northeast, which indicates that, by this hour in the winter, cooling is sufficient for both downslope, from the north slope of the valley, and downvalley winds.

In summary, the predominant wind direction in the Lewiston-Clarkston area is from the east with maxima from that direction during the nighttime hours. Westerly winds are most frequent during afternoon and early evening hours. Because of the steep north slope of the valley, winds having northerly components due to cold-air drainage effects from this slope are much more frequent in Lewiston-Clarkston than are winds with southerly components.

ATMOSPHERIC STABILITY

The diffusion of pollutants in the atmosphere greatly depends upon the stability of the atmosphere, especially the depth of vertical mixing of pollutants.

High-pressure Areas

The existence of high-pressure areas with light winds limiting the horizontal transport of air pollutants and subsidence inversions limiting the vertical mixing of pollutants is important in the assessment of any air pollution problem. Generally associated with high-pressure systems are clear skies, which are conducive to the formation of surface inversions caused by radiation cooling at night; these inversions are rapidly eliminated during the morning hours by solar heating. This rapid elimination of nocturnal radiation inversions is accompanied by inversion breakup fumigation whereby elevated plumes of air pollution are brought to the ground in relatively high concentrations for periods of from half an hour to several hours.[2,3] Klein[4] tabulated the number of high-pressure centers within 5° latitude and 5° longitude squares at 1230 Greenwich Meridian Time for each month for 40 years of record. The relative frequency of high-pressure centers, without regard to speed, for the different months of the year for the square including Lewiston-Clarkston is shown in Figure 2-5. This indicates that from October through February the area is influenced by high-pressure areas almost twice as often as during the period March through September. November, December, and January show the highest frequencies of high pressure from all causes.

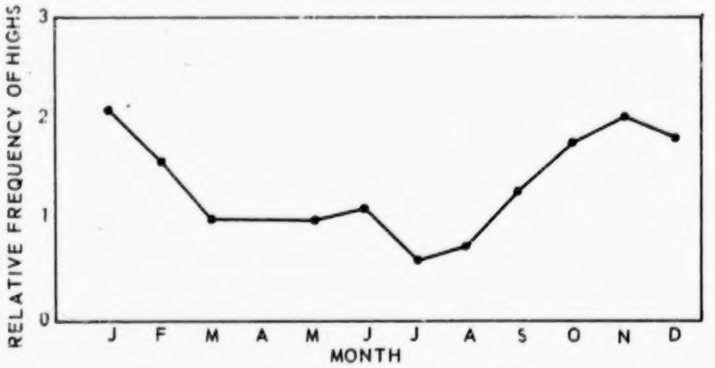

Figure 2-5. Frequency of stagnating high-pressure systems by month in the Lewiston, Idaho, and Clarkston, Washington, area based on 40 years of record.

When a region of high pressure becomes stationary or stagnates, unusually high concentrations of air pollutants can build up. Holtzworth[5] indicates that stagnating high-pressure systems over the western United States are most likely to occur during November and December and estimates that, on the average, about two of these high-pressure systems are likely to affect the Lewiston-Clarkston area each year. Past cases that met the objective criteria and lasted 48 hours or longer during the months of October through January for the years 1957 through 1961 have been studied.[6] Table 2-1 lists the number in the Lewiston-Clarkston area.

Table 2-1. NUMBER OF EPISODES OF POTENTIAL AIR POLLUTION LASTING 48 HOURS OR LONGER IN THE LEWISTON-CLARKSTON AREA

	1957	1958	1959	1960	1961
January		1			1
October					1
November	1	2	2		1
December	1			2	

A model situation of a stagnation episode over the western United States occurred from November 6 through 10, 1959. A Canadian high at the surface spread slowly across western United States and was held intact by the warm ridge aloft. This case is unusual for the Lewiston-Clarkston area because of the extended duration. Surface winds on November 5, 1959, were already light, but on the November 6 and continuing through November 10 all conditions necessary for air pollution prevailed. A study of meteorological data for the fall months of 1957 through 1961 shows this to be the only time that a case of air pollution potential existed a full 5 days.

Inversions

Although no local observations have been made of temperature change with height in the Lewiston-Clarkston area, a general indication of the frequency in percent of inversions and/or isothermal layers based at or below 500 feet above the station elevation is available from Hosler.[7] These data indicate that the fall has the greatest number of hours of inversion. A low-level inversion may be expected to occur during half the hours in the fall.

NORMALITY OF THE SAMPLING PERIOD

Temperature

Monthly temperatures during the sampling period are compared with mean monthly normals in Table 2-2. The largest departure from normal was during November, which was 4.1°F colder than normal.

Heating requirements during the sampling period are compared with the 30-year normal in Table 2-3. Although heating requirements were above normal in November and March, near normal in December, and below normal for the other 3 months, the heating requirements for the 6-month sampling period (4,634 degree-days) were very near normal (4,654 degree-days).

Table 2-2. TEMPERATURES MEASURED AT LEWISTON AIRPORT IN °F

	1961		1962			
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Normal	40.1	34.0	30.7	35.9	42.6	50.8
Sampling period	36.0	34.0	32.1	37.5	41.5	53.5

Table 2-3. HEATING REQUIREMENTS AT LEWISTON IN DEGREE-DAYS

	1961		1962			
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Normal[a]	747	961	1,060	815	663	408
Sampling[b]	847	950	1,013	764	724	336

[a] Total degree-days for normal period, 4,654.
[b] Total degree-days for sampling period, 4,634.

Precipitation

November and March had more than normal, December had near normal, and the other 3 months had lower than normal precipitation (Table 2-4). December had a greater than normal and the other months had a near normal number of days with precipitation (Table 2-5). Consequently, it is not expected that the number of days with

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precipitation, except in January which had only 7, compared with the expected number, 12, had any great influence upon the air pollution levels in the Lewiston-Clarkston area.

Table 2-4. PRECIPITATION AT LEWISTON IN INCHES

	1961		1962			
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Normal	1.35	1.30	1.05	1.00	1.14	1.14
Sampling period	2.14	1.10	0.51	0.76	1.43	0.43

Table 2-5. NUMBER OF DAYS WITH
PRECIPITATION 0.01 INCH OR MORE

	1961		1962			
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Normal	10	11	12	10	11	9
Sampling period	10	17	7	8	13	6

WIND

Wind Speed

Figure 2-6 illustrates the percent frequency of winds from 0 to 3 mph at both the post office and the airport for four periods, each including 3 observational hours at different times of day for January and February (winter months) and for March and April (spring months) of 1962. This graph cannot be compared directly with Figure 2-4, which is based on 5 years of record for the two stations, since the latter is based on 1-hour periods and for 3 months instead of 2, but the fact that the percents of these low wind speeds are considerably less than those for the 5-year period indicates that there was a higher frequency of wind speeds greater or equal to 4 mph during these 4 months and that March and April were considerably windier than usual.

Wind Direction

Figure 2-7 shows wind roses for 3 successive hours for four periods of the day for two seasons during the study, both at the post office and the airport.

The months of January and February had higher frequencies of winds from the northeast quadrant at the post office than would normally

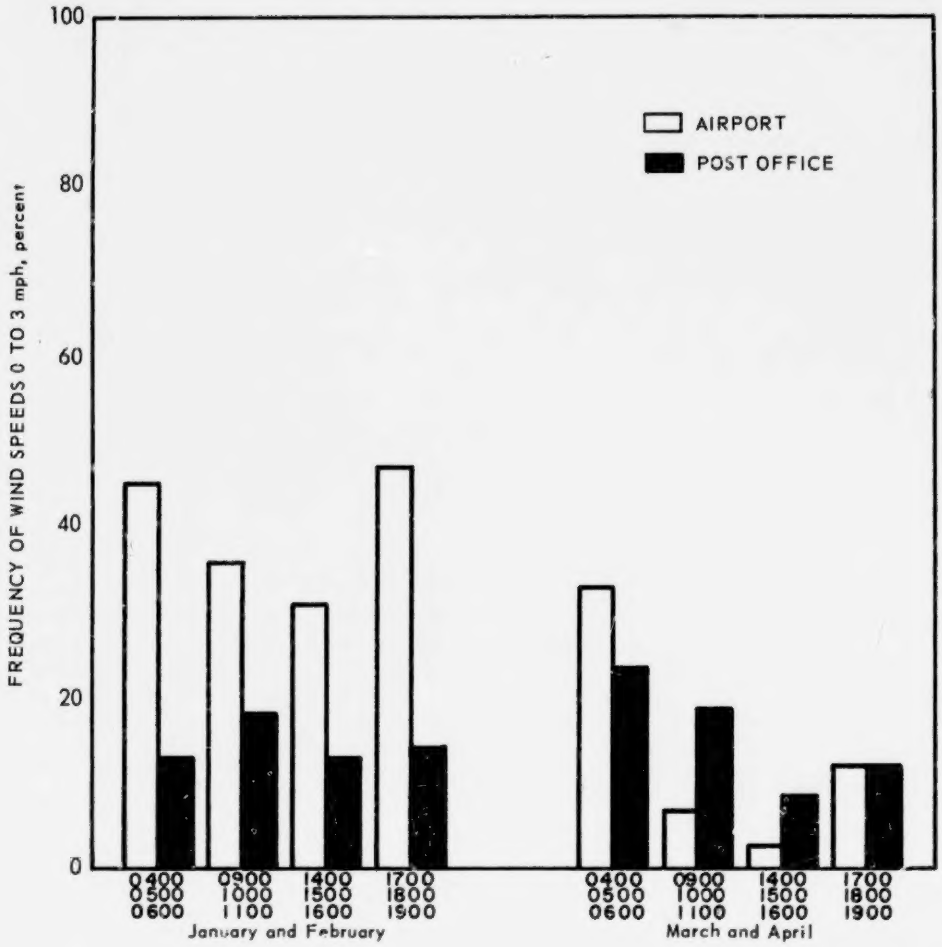

Figure 2-6 Frequency of wind speeds 0 to 3 mph for selected hours in Lewiston, Idaho, January and February and March and April 1962.

be expected. Winds at the airport during these 2 months seemed to have increased frequencies from both the northwest and southwest quadrants.

During March and April higher frequencies of westerly winds were also noted, showing an increased frequency of west-southwest winds at the post office and increased frequencies of west through northwest winds at the airport.

ATMOSPHERIC STABILITY

Temperatures were compared from hygrothermograph records at the post office and at the airport for the months of January through April 1962. When the temperature at the post office was lower than or equal to the temperature at the airport, atmospheric conditions for that hour were estimated to be stable. The number of hours with stable

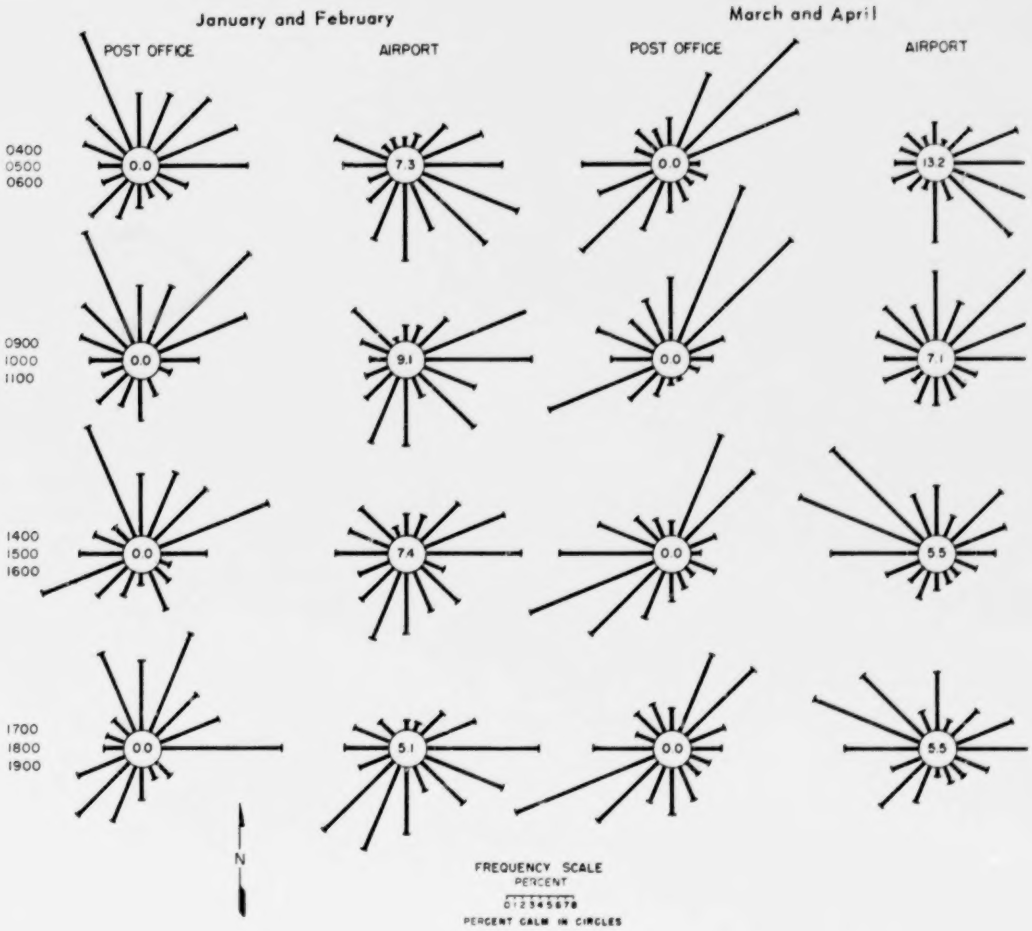

Figure 2-7. Wind direction frequencies for selected hours, Lewiston, Idaho, January-April 1962.

conditions was determined for each month. The monthly percentages of hours with stable conditions were January, 28 percent; February, 27; March, 15; and April, 10.

UNUSUAL WEATHER

The snowstorm on November 23 through November 25, 1961, was one of the heaviest November snowfalls on record. Record low temperatures for the dates were set on February 24, 25, 26, and 27, 1962. On April 24 a windstorm causing minor damage occurred. The peak observed velocity at the airport, west-northwest 55 mph with gusts to 65, was observed at 1358 hours.

CONCLUSIONS REGARDING NORMALITY

From January through April 1962 (wind observations were available at both the post office and the airport), air pollution concentrations could be expected to be less than during a normal January-through-April period, because of the higher than normal wind speeds and because of the lower than normal frequency of easterly winds, which tend to move pollutants from the major source toward Lewiston-Clarkston.

SUMMARY

Lewiston and Clarkston are in a Y-shaped river valley with a range of foothills to the north sloping to above 2,000 feet above the river. The local meteorological conditions are greatly influenced by topography. Low wind speeds frequently occur, particularly during the early morning hours. The predominant wind direction is from the east with maxima from that direction during the nighttime hours. Westerly winds are most frequent during afternoon and early evening hours. High-pressure areas with light winds limiting the horizontal transport of air pollutants and subsidence inversions limiting the vertical mixing of air pollutants can affect the region in all months, and stagnating highs lasting 48 hours or longer are common in the months of October through January with most likely occurrences in November. The fall season has the greatest number of hours of inversion; a low-level inversion is expected to occur during half the hours.

During the period of the interstate study, air pollution concentrations could be expected to be less than during a normal *January through April* period, because of the higher than normal wind speeds, and because of the lower than normal frequency of easterly winds. Winds from an easterly direction tend to move pollutants from the major source toward Lewiston-Clarkston, thereby increasing air concentrations.

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CHAPTER III. SOURCES OF AIR POLLUTION

An inventory of emissions was made for the Lewiston-Clarkston area with information provided by the two communities and the industries of the area. This inventory is as close an estimation of emissions as was possible with available data and is useful in indicating the relative importance of various sources of air pollution.

These sources of pollution have been divided into: kraft mill, other industries, fuel usage, and refuse disposal. Each is discussed in detail with a list of assumptions used in estimating emissions. The total emission estimate is presented in Table 3-1.

The operations of the kraft mill emit hydrogen sulfide (H_2S) and other malodorous organic gases to the atmosphere. The odor potentials of these materials are delineated below.[1]

Substance and formula	Approximate minimum perceptible concentration, ppb
Hydrogen sulfide (H_2S)	1
Methyl mercaptan (CH_3SH)	1
Dimethyl sulfide (CH_3SCH_3)	10
Dimethyl disulfide (CH_3SSCH_3)	10

The difficulty of odor control becomes apparent from these threshold odor data. The problem is further accentuated by the many possible points of emission. Of the total estimated emissions listed in Table 3-1, the kraft mill contributes about 77 percent of gaseous emissions and about 82 percent of the solid particulate emissions. The kraft mill data indicate that the major gaseous emissions are "combustibles" discharged from the recovery furnaces and lime kilns. Comparing recovery furnace emission data supplied by the kraft mill and information in published articles[2,3,4,5] resulted in the assumption that the recovery furnaces were, from an air pollution standpoint, either overloaded or inefficiently operated; however, recent information from Potlatch Forests, Inc. states that the three recovery furnaces have "a total capacity of 2,244,000 pounds of black liquor solids per day."[6] On the basis of 2,800 pounds of black liquor solids per ton of pulp produced, the furnaces are capable of handling a pulp production of 800 tons per day, i.e., 150 tons per day in excess of the operating rate during the aerometric study. Potlatch further reports[6] recent changes in the operation of the recovery furnaces wherein the oxygen content of the flue gases has been increased two- to threefold. These changes should effect a reduction in the emission of odorous sulfur compounds from the recovery furnaces.

Table 3-1. TOTAL ESTIMATED AIR CONTAMINANT EMISSIONS IN THE LEWISTON-CLARKSTON AREA (lb/day)

Pollutants	Industrial		Domestic-commercial		Trans-portation	Total
	Potlatch Forest Inc.	Other	Heating	Refuse disposal		
Sulfur oxides	1,214	21	4,026	68	155	5,484
Nitrogen oxides	3,757	198	2,961	90	2,207	9,213
Hydrocarbons	1,285	2,625	2,116	135	6,619	12,780
Aldehydes	149	236	210	225	111	931
Organic acids	112	54	Neg	Neg	46	212
"Combustible" (as CO)	289,100[a]	Neg	Neg	904[b]	65,800[b]	355,804
Ammonia	-	-	-	-	44	44
Hydrogen sulfide	4,256	-	Neg	-	-	4,256
Methyl mercaptan	89	-	-	-	-	89
Dimethyl sulfide	110	-	-	-	-	110
Other organic gases	-	Neg	Neg	181	-	181
Total gaseous pollutants	300,072	3,134	9,313	1,603	74,982	389,104
Total particulate matter[c]	20,076	2,057	1,774	496	12	24,415

[a] Combustible emission from lime kilns and recovery furnaces consist of carbon monoxide and organics.

[b] Carbon monoxide.

[c] Include solids from industrial operation.

Large quantities of water vapor are also emitted from the kraft mill; these may have adverse effects on visibility in the valley under certain meteorological conditions. It has been found to be feasible in parts of Europe to extract heat from the emissions from paper machines and pulp driers,[7,8] thus reducing water emitted, but the economic feasibility of such practice in this country was not determined during this study.

Hydrocarbons and particulates are the major emissions from industrial operations other than the kraft mill, but these sources are relatively small and of lesser importance to the community as a whole. Home heating is a substantial source of sulfur and nitrogen oxides, hydrocarbons, and particulate matter. Transportation is a major contributor of hydrocarbons and a substantial amount of carbon monoxide to the air. Emissions from fuel usage are so distributed over the community that large concentrations in any one area are uncommon.

Refuse disposal is a relatively minor source of air pollutants, though the odor produced by burning garbage and refuse cannot be neglected. Periodic local complaints of odor and smoke from refuse burning might be expected, but this source does not constitute a problem for the area as a whole.

INDUSTRIAL OPERATIONS

Employment figures for Nez Perce County, which include Lewiston, Idaho, are presented in Tables 3-2 and 3-3. The largest single industrial category is obviously the lumber industry. In this area alone, over 250 million board feet of lumber are produced annually, over and above the output of the PFI pulp mill. Food processing and construction are other major industries.

Table 3-2. NUMBER OF NEZ PERCE COUNTY EMPLOYERS IN 1959 BY BUSINESS CLASSIFICATION [a]

Mining	6
Construction	81
Manufacturing	56
Transportation, communication, utilities	36
Trade	
Wholesale	47
Retail	254
Financial institutions	53
Services	
Business	99
Professional	95
Other employment	5
Total 1959 employers	732

[a] Nonagricultural employers of one or more reporting to Idaho Employment Security Agency.

Table 3-3. AVERAGE 1959 NEZ PERCE COUNTY NONAGRICULTURAL EMPLOYMENT AND PAYROLL [a]

Mining	16
Construction	279
Food produce	305
Lumber	1,820
Other	934
Transportation, communication, utilities	441
Wholesale, retail trade	2,031
Finance institutions, real estate	266
Services, etc.	852
Average totals [b]	6,944
Total payrolls covered by Employment Security Agency (thousands)	$31,078

[a] Includes only those covered by Employment Security Law.

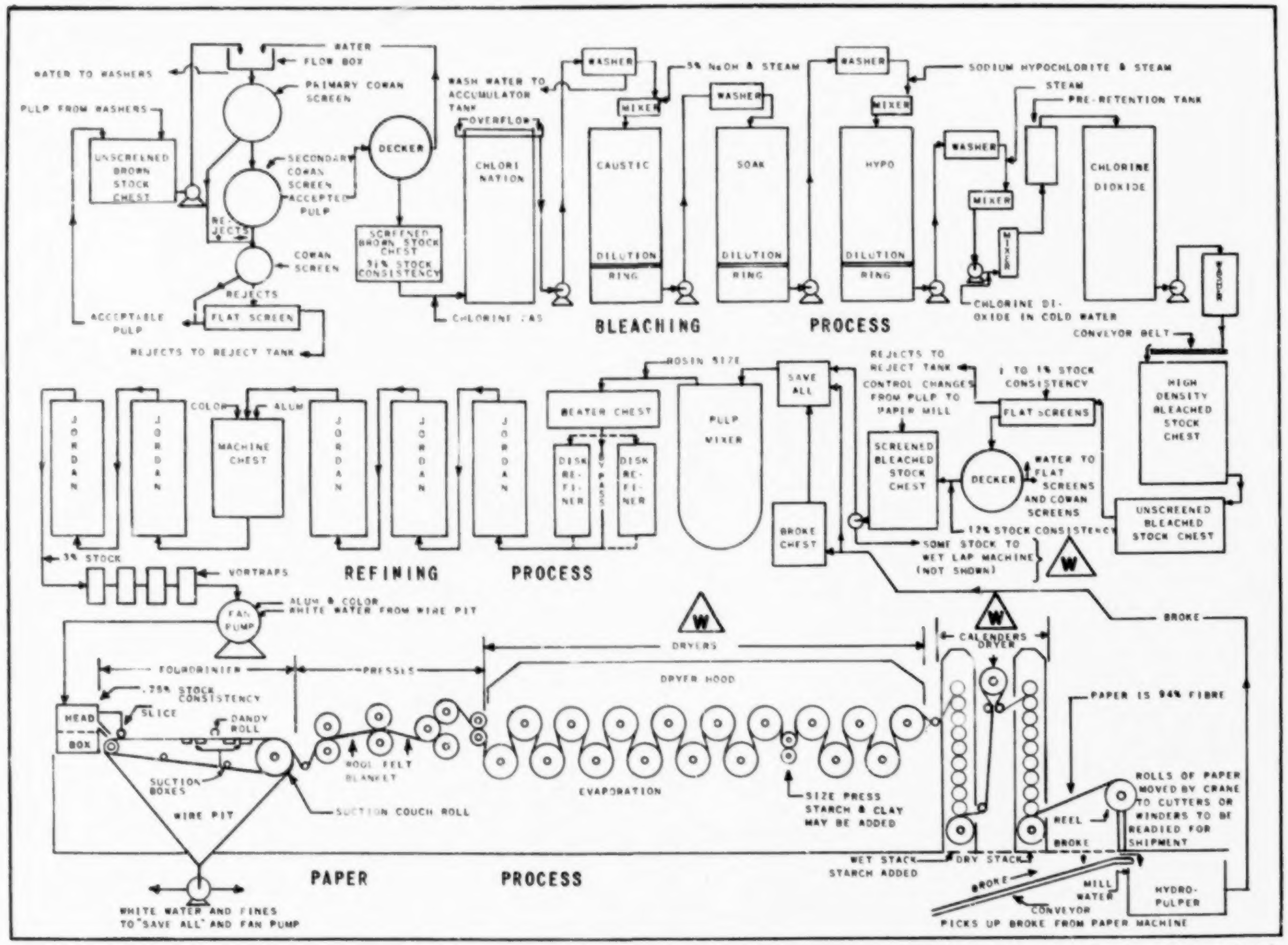
[b] Totals include state employes not previously under Employment Security Law.

SULFATE (KRAFT) PULP MILL

Process Description

The pulp mill in Lewiston, Idaho, produces 450 tons per day of bleached paperboard and an additional 200 tons per day of market pulp by the kraft process. Simplified flow diagrams of the mill showing points of major pollutant emissions are given in Figures 3-1 and 3-2.

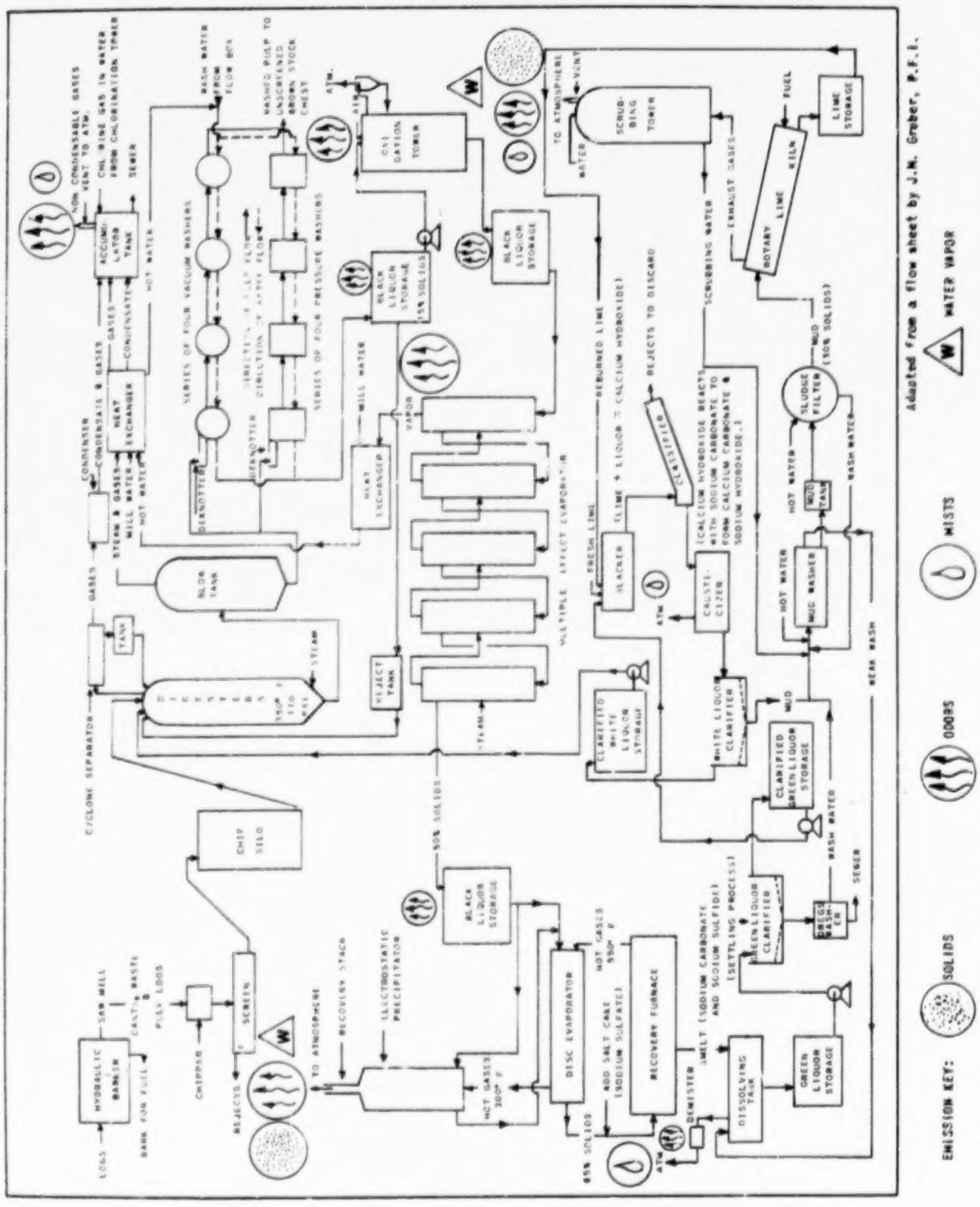
After the logs are stripped of bark, sawed, and chipped, the chips are charged into the digesters and cooked for approximately 3 hours in a solution containing sodium sulfide and sodium hydroxide. During this time, sufficient live steam is injected to reach and maintain a pressure of 110 psia. As steam is added, the gases are driven off as relief gases and are treated by a cyclone separator that removes small quantities of wood chips and cooking-liquor carryover. At the end of the cook, the chips and spent black liquor are transferred into "blow" tanks by steam pressure in the digesters. As the charge undergoes a decrease in pressure, further steam is generated in the blow tanks. This steam or "blow gas" is used to heat water for the pulp washing process. Untreated blow and relief gases can be one of the


WATER
FLOW BOX
WATER TO WASHERS
PULP FROM WASHERS
PRIMARY COWAN SCREEN
UNSCREENED BROWN STOCK CHEST
SECONDARY COWAN SCREEN
ACCEPTED PULP
REJECTS
COWAN SCREEN
DECKER
SCREENED BROWN STOCK CHEST 3½% STOCK CONSISTENCY
ACCEPTABLE PULP
FLAT SCREEN
REJECTS TO REJECT TANK
WASH WATER TO ACCUMULATOR TANK
OVERFLOW
CHLORINATION
CHLORINE GAS
WASHER
MIXER
CAUSTIC
DILUTION RING
5% NaOH & STEAM
SOAK
HYPO
SODIUM HYPOCHLORITE & STEAM
STEAM
PRE-RETENTION TANK
CHLORINE DIOXIDE
CHLORINE DIOXIDE IN COLD WATER
CONVEYOR BELT
BLEACHING PROCESS
JORDAN
COLOR
ALUM
MACHINE CHEST
BEATER CHEST
DISK REFINER
BY PASS
ROSIN SIZE
PULP MIXER
SAVE ALL
BROKE CHEST
REJECTS TO REJECT TANK
CONTROL CHANGES FROM PULP TO PAPER MILL
1 TO 1% STOCK CONSISTENCY
FLAT SCREENS
SCREENED BLEACHED STOCK CHEST
WATER TO FLAT SCREENS AND COWAN SCREENS
12% STOCK CONSISTENCY
SOME STOCK TO WET LAP MACHINE (NOT SHOWN)
HIGH DENSITY BLEACHED STOCK CHEST
UNSCREENED BLEACHED STOCK CHEST
W
3% STOCK
VORTRAPS
REFINING PROCESS
ALUM & COLOR
WHITE WATER FROM WIRE PIT
FAN PUMP
FOURDRINIER
PRESSES
DRYERS
CALENDERS
DRYER
BROKE
.75% STOCK CONSISTENCY
HEAD BOX
SLICE
DANDY ROLL
SUCTION BOXES
WIRE PIT
SUCTION COUCH ROLL
WOOL FELT BLANKET
DRYER HOOD
EVAPORATION
SIZE PRESS STARCH & CLAY MAY BE ADDED
PAPER IS 94% FIBRE
ROLLS OF PAPER MOVED BY CRANE TO CUTTERS OR WINDERS TO BE READIED FOR SHIPMENT
REEL
WET STACK STARCH ADDED
DRY STACK
MILL WATER
HYDRO-PULPER
CONVEYOR PICKS UP BROKE FROM PAPER MACHINE
WHITE WATER AND FINES TO "SAVE ALL" AND FAN PUMP
PAPER PROCESS

Adapted from a flow sheet by J. M. Gruber, P.F.I.

W Major water vapor emissions

Figure 3-1. Flow diagram of sulfate pulp mill papermaking process.


LOGS
HYDRAULIC BARKER
BARK FOR FUEL
SAW MILL
CANT, SLABS, BOLTS & PLAY LOGS
CHIPPER
SCREEN
REJECTS
CHIP SILO
CYCLONE SEPARATOR
TANK
GASES
DIGESTER
STEAM
REJECT TANK
BLOW TANK
CONDENSER
HEAT EXCHANGER
ACCUMULATOR TANK
NON CONDENSABLE GASES VENT TO ATM.
SEWER
HOT WATER
SERIES OF FOUR VACUUM WASHERS
SERIES OF FOUR PRESSURE WASHERS
WASH WATER FROM FLOW BOX
WASHED PULP TO UNSCREENED BROWN STOCK CHEST
DEKNOTTER
BLACK LIQUOR STORAGE
15% SOLIDS
OXIDATION TOWER
ATM.
MILL WATER
VAPOR
HEAT EXCHANGER
MULTIPLE EFFECT EVAPORATOR
50% SOLIDS
STEAM
TO ATMOSPHERE
RECOVERY STACK
ELECTROSTATIC PRECIPITATOR
HOT GASES 300° F
HOT GASES 550° F
DISC EVAPORATOR
65% SOLIDS
ADD SALT CAKE (SODIUM SULFATE)
RECOVERY FURNACE
SMELT (SODIUM CARBONATE AND SODIUM SULFIDE)
DEMISTER
DISSOLVING TANK
GREEN LIQUOR STORAGE
GREEN LIQUOR CLARIFIER (SETTLING PROCESS)
DREGS WASHER
WASH WATER
CLARIFIED GREEN LIQUOR STORAGE
WHITE LIQUOR CLARIFIER
CLARIFIED WHITE LIQUOR STORAGE
MUD
SLACKER
FRESH LIME
REBURNED LIME
LIME + LIQUOR = CALCIUM HYDROXIDE
CLASSIFIER
REJECTS TO DISCARD
CAUSTICIZER
(CALCIUM HYDROXIDE REACTS WITH SODIUM CARBONATE TO FORM CALCIUM CARBONATE & SODIUM HYDROXIDE.)
MUD WASHER
MUD TANK
HOT WATER
SLUDGE FILTER
MUD (50% SOLIDS)
WEAK WASH
ROTARY LIME KILN
EXHAUST GASES
SCRUBBING WATER
SCRUBBING TOWER
WATER
TO ATMOSPHERE VENT
FUEL
LIME STORAGE
EMISSION KEY:
SOLIDS
ODORS
MISTS
WATER VAPOR
THE SIZE OF THE CIRCLE INDICATES THE RELATIVE MAGNITUDE OF THE SOURCE

Adapted from a flow sheet by J.N. Greber, P.F.I.

Figure 3-2. Process flow sheet showing sulfate pulp mill chemical recovery system and points of pollutant emissions.

major sources of odorous gases in the kraft pulp mill.

The pulp and black liquor are next pumped from a blow tank to a deknotter where the fibers and liquor are separated. From the deknotter the liquor is pumped to storage for further treatment in a chemical recovery system, and the pulp is sent through a series of either vacuum or pressure washers. In the vacuum system, the stock is washed with water and then somewhat dehydrated by a vacuum maintained throughout the washer series. The pressure system also dilutes the pulp, but removes water by squeezing the stock in an auger-type pressure apparatus. The washed pulp is then thickened by further removal of water and made ready for the bleaching process. The thickened pulp is run through a chlorinator tank, causticizer tank, and sodium hypochlorite tank to destroy dyes formed from tannins present in the wood. The bleached stock is next refined to a consistency specified by the customer. The refined stock is then moved onto a screen and formed into a sheet. Finally, the sheet is run through a Fourdrinier machine, dried, rolled, and shipped to market.

Returning to the black liquor storage tank, the solution is now ready for the chemical recovery cycle (Figure 3-2).

At this point, the liquor consists of a mixture of water, sodium-lignin salts, sodium sulfide, and appreciable amounts of organic sulfur compounds. The total solids content is about 15 percent. A small portion of the liquor is diverted back to the digester for an incoming cook, and the remainder is sent through one of three oxidation towers. The function of the tower is to oxidize the organic sulfur compounds and "fix" them into the solution to eliminate odors that would otherwise evolve from the evaporators.

Leaving the towers, the liquor is sent through one of three sets of multiple-effect evaporators where the black liquor is concentrated from 15 to 50 percent solids.

Next, the liquor is put through a disc evaporator employing hot gases at 550°F produced in the recovery furnace to concentrate the solution further to 65 percent solids. As the solution leaves the evaporator, salt cake (Na_2SO_4) is added to it to make up chemical losses, and then the liquor is sprayed into one of three recovery furnaces.

Within the furnaces, reducing conditions are maintained by limiting the amount of air admitted. Such an atmosphere results in the reduction of sodium sulfate to sodium sulfide, which is the desired product for later use in the digester cooking liquor. The smelt that runs from the base of the recovery furnace consists primarily of sodium sulfide and sodium carbonate, the latter being a product of sodium organic salt combustion occurring in the furnace.

The smelt is dissolved in water in the dissolving tank to produce what is called green liquor. The green liquor is clarified in a settling tank, and the suspended solids are drained out, washed, and sewered.

The clarified green liquor is then sent to a slaker where lime is added.

The lime reacts with the sodium carbonate in the green liquor to form sodium hydroxide and precipitate calcium carbonate. The causticized solution is clarified to remove calcium carbonate and other suspended solids. The resulting solution, called "white liquor," is pumped to storage for reuse in the digester cooking process.

The settled solids, called lime mud, that emerge from the bottom of the clarifier consist primarily of calcium carbonate and sodium compounds. The sludge is moved through a mud washer where it is diluted with a large quantity of water to recover the soluble sodium salts. The settled mud is then run through a sludge filter and charged to one of three rotary lime kilns for ignition. Here, the calcium carbonate is converted to lime for later use in causticizing the green liquor.

Emission Sources

Obnoxious odors associated with the kraft process are attributable to sodium sulfide in the cooking liquor. Although the chemistry involving the dissolution of noncellulosic portions of the wood is not completely understood, the use of sodium sulfide in the cooking liquor hastens the kinetics of the reaction by approximately 20 percent.

During the 3- to 8-hour cook, the sulfide ion reacts with hydrogen and wood organics to form hydrogen sulfide (H_2S), and organic sulfides such as methyl mercaptan (CH_3SH), dimenthyl sulfide (CH_3SCH_3), and dimethyl disulfide (CH_3SSCH_3). Although volatile sulfur emissions may be fairly low in a highly controlled plant, an odor nuisance may occur because each of the above contaminants is, in itself, capable of producing a disagreeable odor at a concentration of less than 1 ppm. In particular, the lighter mercaptans have an extremely disagreeable odor at very small concentrations.

Major sources of air pollutants are:

1. Solid emissions
   a. recovery furnace
   b. lime kilns
   c. boiler plant
2. Odorous gases
   a. recovery furnace
   b. digester relief and blow gases
   c. lime kiln
   d. evaporators
   e. boiler plant
3. Mists
   a. recovery furnace
   b. smelt tank
   c. lime kiln
   d. causticizer
   e. digester
   f. blow tank

There are also many other minor sources of emissions from the chemical recovery system.

Emissions from Digester Relief and Blow Gas Systems

Malodors associated with the blow system are carried by the relief and blow gases released during the cooking cycle. Control equipment used to reduce these emissions is shown in Figure 3-2. Relief gases are first run through a cyclone separator that removes small quantities of entrained wood chips and cooking liquor and are then sent to a condenser. The condensate and remaining gases are next run to an accumulator tank for chlorination treatment. Blow gases evolving from the pressurized removal of the pulp from the digester to the blow tanks are partially condensed in a heat recovery system and then passed to the same accumulator tank.

Wash water containing chlorine gas from the chlorination tower is sprayed into the accumulator tank. Water-soluble gases are directly washed into solution, and chlorine gas oxidizes the odorous materials in the gases. Finally, the noncondensable gases are vented to the atmosphere.

Emission factors for sulfur compounds in the digester gases were estimated by use of the data of DeHaas and Hansen[9] and are given in Table 3-4. The chlorination treatment of the digester gases and condensate is reported to be effective in reducing odorous emissions if the proper amounts of chlorine are used. If an efficiency of 98 percent is assumed, the sulfur compounds emitted are approximately as shown in Table 3-5. These estimates indicate that H_2S emissions may be insignificant, but that the possibility exists for an odor problem from the CH_3SH and CH_3SCH_3 emissions.

Table 3-4. EMISSIONS FACTORS FOR DIGESTER GASES [a]

Digester cooking conditions	Pollutants per ton of pulp produced, lb		
	Hydrogen sulfide	Methyl mercaptan	Dimethyl sulfide
Cook time - 3.45 hr Temperature - 172°C Sulfidity - 22.5%	0.66	5.3	3.8

[a] Reference 9.

Table 3-5. ESTIMATED EMISSIONS FROM ACCUMULATOR TANK

	Gaseous pollutant		
	H_2S	CH_2SH	CH_3SCH_3
Entering accumulator tank, lb/day	430	3,460	2,470
Assumed efficiency of chlorination, %	98	98	98
Leaving accumulator in vent gas, lb/day	8.6	39.0	50.0

Emissions from Recovery Furnace

The function of the recovery furnace is to reduce the sodium sulfate present in the black liquor to sodium sulfide for later use in the cooking cycle. To accomplish this, a reducing atmosphere is maintained within the "primary reaction zone" by limiting the amount of combustion air admitted. Reducing conditions are, however, favorable for the formation of H_2S as well as other organic sulfides.

Introduction of secondary air higher in the furnace chamber has proved effective for the oxidation of H_2S to SO_2. Within this reaction zone, oxidizing conditions are maintained by admitting additional combustion air. H_2S emissions as a function of oxygen composition of stack gases are shown in Figure 3-3, together with the oxygen content of flue gases from the three recovery furnaces at Potlatch Forests, Incorporated (PFI).

Each of the three furnaces is individually vented to the atmosphere after treatment by a separate control device. Furnaces 1 and 2 are vented to Cottrell electrostatic precipitators with flyash removal efficiencies of 83 and 88 percent respectively. Furnace 3 is controlled by a venturi scrubber with about an 80 percent efficiency. These values are somewhat lower than efficiencies reported in the literature for similar installations. [2,5,10,11]

Flyash and H_2S concentrations prior to treatment and final emissions afterward are reported for each of the flue gas streams (Table 3-6). Of the control devices, probably only the venturi scrubber effects H_2S removal. A study of Table 3-6 reveals the recovery furnace to be the predominant source of flyash and H_2S.

Methods that can be used to reduce H_2S emissions from recovery furnaces include introduction of adequate secondary combustion air and the scrubbing of the flue gases with white liquor. Figure 3-3 indicates that an oxygen content of 2 to 3 percent in furnace flue gas can permit oxidation of H_2S and other sulfur compounds to the less odorous SO_2. It should be noted, however, that the mere presence of excess oxygen in

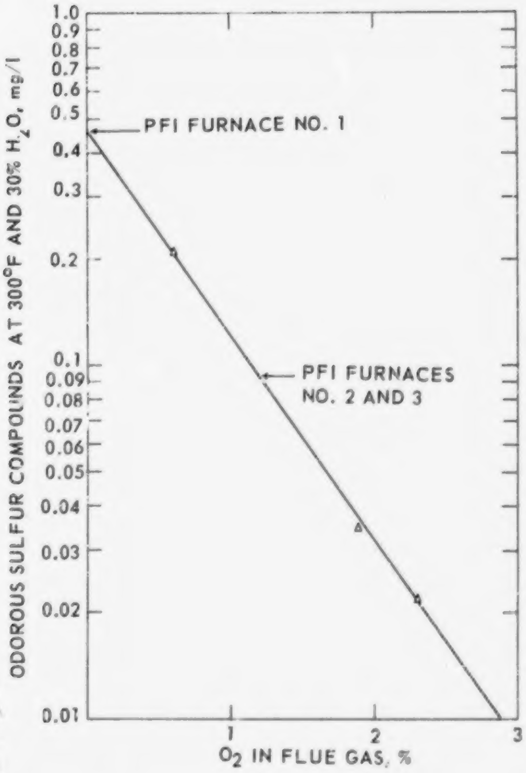


Figure 3-3. Percent oxygen in flue gas vs. odorous sulfur compound emission (Reference 9).

the effluent gases does not ensure combustion of odorous gases if the secondary air is not properly mixed with the gases to be burned.

The result of oxygen deficiencies in the three recovery furnaces is readily apparent by the amount of the combustible emission shown in Table 3-6. This emission was calculated on the basis of data supplied by the kraft mill. It was assumed that about half of this material is carbon monoxide and that the remainder consists of organic compounds.

Recent information[6] from the kraft mill is quoted as follows: "The data provided to the U.S.P.H.S. indicated an oxygen content of 0% for No. 1 recovery boiler and 1.2% for Nos. 2 and 3 recovery boilers. These figures are believed to be reasonably correct at that time. However, Potlatch is presently trying to operate the recovery boilers with 2-3% excess oxygen consistent with recent industry trends and techniques. Examination of records for the past two months indicate the following:

Recovery boiler	% Excess oxygen
No. 1	0.4 to 4.0
No. 2	0.0 to 2.0
No. 3	0.5 to 1.5

"The wide range of values reported above have been due, in part, to operational difficulties which have been rectified during the 1963 Christmas shut-down."

On the basis of this new information, the emission of odorous sulfur compounds from the recovery furnaces should be reduced.

Emissions from Evaporators

The innovation of black liquor oxidation treatment constitutes the most effective measure yet taken by the industry to eliminate odors evolving from a single process step. Thus, a discussion of odorous emissions from the evaporators relates directly to the oxidizing efficiencies of the oxidation towers. The efficiency of the three oxidation towers at the kraft mill is reported to be 50 percent; thus, the odor-reducing potential of this equipment is not fully realized.

Table 3-6. ESTIMATE OF GASEOUS AND SOLID EMISSIONS FROM THE RECOVERY FURNACES

Item	Furnace number			Total
	1	2	3	
Particulate generated, lb/day	14,100	38,000	27,200	79,300
Particulate control equipment	Electrostatic precipitator	Electrostatic precipitator	Venturi scrubber	-
Control equipment efficiency, %	83	88	80.4	-
Particulate emitted, lb/day	2,390	4,550	5,370	12,310
"Combustible" emitted, lb/day [a]	34,400	72,600	34,400	141,400
Hydrogen sulfide emitted, lb/day	2,000	1,000	120[c]	3,120
Sulfur dioxide, lb/day [b]	220	560	400	1,180

[a] "Combustible" consists of carbon monoxide and organic material.

[b] Assumed 30 ppm in flue gases of furnaces.

[c] Assumed 80 percent removal of H_2S.

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If unoxidized black liquor is fed into the evaporators, the resulting vapor phase is highly concentrated with H_2S and CH_3SH. Bergstrom and Trobeck [12] have investigated these losses, and their results are reported in Table 3-7, along with the estimated emissions from this source.

Table 3-7. ESTIMATED EMISSIONS FROM EVAPORATORS [a]

	Pollutant	
	Hydrogen sulfide	Methyl mercaptan
Emission factor, lb/ton of pulp	1.2	0.06
Potential emission, lb/day	780	40
Oxidation tower efficiency, %	50 [b]	50 [b]
Estimated emission, lb/day	390	20

[a] Reference 12.

[b] Communication from Idaho Department of Health, Sept. 24, 1962.

Emissions from Oxidation Towers

In a properly operated black liquor oxidation tower, a significant emission of H_2S or CH_3SH is not likely but CH_3SSCH_3 and CH_3SCH_3 may be present. For this inventory, it was assumed that the effluent from each oxidation tower contained 1 ppm of CH_3SCH_3, [13] which totals approximately 60 pounds per day. Odorous gases from this source can be controlled by chlorination in a manner similar to that employed for digester relief and blow gases.

Emissions from Lime Kilns

The calculated emissions from the lime kilns are given in Table 3-8. The particulate and combustible emissions are based on data reported by PFI. The particulate or dust emission of 6,269 pounds per day could be an important contributor to a localized air pollution problem.

Again it is noted that the emission of "combustibles" is excessive. This combustible material is probably about half carbon monoxide and the remainder organics. On the assumption that each kiln exhaust contains 100 ppm H_2S, it is seen that the 730 pounds per day emission could significantly contribute to an odor problem. As with the recovery furnaces, the proper use of adequate combustion air can reduce H_2S and other combustible emissions.

Calculations of other contaminant emissions, nitrogen oxides, aldehydes, and organic acid were based on the amount of natural gas fired in the kilns.

Table 3-8. ESTIMATED EMISSIONS FROM LIME KILNS

	Emission, lb/day			
	Kiln No. 1	Kiln No. 2	Kiln No. 3	Total
Particulate matter	724	1,105	4,440	6,269
Total combustible [a]	15,700	17,000	115,000	147,700
Hydrogen sulfide	137	148	452	737
Sulfur oxides as SO_2		6		6
Nitrogen oxides as NO_2		847		847
Aldehydes as formaldehyde		8		8
Organic acid, as HAc		20		20

[a] Combustible emission probably consists of carbon monoxide and organics.

Emissions from Dissolving Tanks

The hot smelt that enters the dissolving tanks from the recovery furnaces tends to shatter and results in the emission of mists and solid particulates. This emission was estimated to be 17 pounds per ton of pulp.[14] Each dissolving tank is equipped with a mesh demister assumed to be 90 percent efficient. On this basis, total particulate discharge to the atmosphere was calculated to be 1,100 pounds per day.

There is also the possibility of odorous emissions from these tanks, but it was not feasible to attempt an estimate.

Emissions of Water Vapor

Water vapor can be considered an air pollutant because of its contribution to the reduction in visibility. It is conceivable that large water vapor emissions could combine with particulate material to cause more and longer lasting fogs than would be ordininarily expected.

In the manufacture of pulp and paper, large quantities of water are essential for pulp washing, dilution and transport, steam generation, cooling, and numerous other uses. The kraft mill requires an average of 40 million gallons of water each day, most of which is returned to the river. Of this total water requirement, more than 2 percent is lost to the atmosphere. Major sources of water vapor emission are the recovery furnaces, lime kilns, paper machines, pulp dryer, and combustion of fuels. The total water vapor emission is estimated to be about 4,640 tons per day (Table 3-9). This amount of water vapor, from essentially a point source, is equivalent to about 25 percent of the water vapor generated by the combustion of all types of fuel in the entire Lewiston-Clarkston area during the heating season.

Humidity data taken during this study, when compared with data from 1924 to 1933, show that a significant increase has occurred (see Table 4-6, p. 67). Water vapor emission from PFI undoubtedly increases humidity in the valley atmosphere under certain meteorological conditions.

Table 3-9. ESTIMATED WATER VAPOR EMISSIONS FROM THE PULP MILL

Source	Water vapor emitted	
	Tons/day	Gal/day
Recovery furnaces	1,389	333,000
Lime kilns	925	222,000
Paper machines	891	214,000
Pulp dryer	160	38,400
Boilers (gas fired)	1,275	306,000
Total	4,640	1,113,400

Emissions from Mill Boilers

It was assumed that all boilers were gas fired; their emissions are tabulated in Table 3-10. When these boilers are oil fired, the emissions of particulates, nitrogen oxides, etc., increase substantially.

Summary of Emissions from Kraft Pulp Mill

Since no stack gas analyses were made at the kraft mill, the emissions reported in previous sections and summarized in Table 3-10 are estimates. The basis for these estimates was information provided by the mill and a literature review. The emission estimates are not to be construed as absolute values and are deemed useful only in showing the relative importance of various air pollutant sources. Not included in this report are estimates of emissions from storage tanks, leaks, hold-

Table 3-10. SUMMARY OF ESTIMATED EMISSIONS FROM KRAFT PULP MILL

Process or equipment source	Emissions, lb/day										
	Hydrogen sulfide	Methyl mercaptan	Dimethyl sulfide	Solid particulates	Combustibles [a]	Sulfur oxides as SO_2	Nitrogen oxides as NO_2	Aldehydes as formaldehydes	Organic acids as HAc	Hydrocarbons	Water vapor
Digester gases	9	69	50	-	-	-	-	-	-	-	-
Evaporators	390	20	neg.	-	-	-	-	-	-	-	-
Recovery furnaces	3,120	neg.	neg.	12,310	141,400	1,180	c	-	-	-	2,778,000
Smelt tanks	c	c	c	1,100	-	-	-	-	-	-	-
Lime kilns	737	c	c	6,269	147,700	6 [b]	847	8	20	-	1,850,000
Oxidation towers	c	c	60	-	-	-	-	-	-	-	-
Plant boilers [d]	-	-	-	397	neg.	28 [b]	2,910	141	92	1,285	2,550,000
Paper machines	-	-	-	-	-	-	-	-	-	-	1,782,000
Pulp dryer	-	-	-	-	-	-	-	-	-	-	320,000
Total	4,256	89	110	20,076	289,100	1,214	3,757	149	112	1,285	9,280,000

[a] Combustible emission probably consists of carbon monoxide and other organic materials.

[b] Assumed sulfur content of natural gas, 0.4 grain/100 ft^3.

[c] Indicated pollutant present in emissions, but amount is unknown.

[d] Emissions include those from burning waste wood.

ing ponds, and other minor sources although the emission from each source may be small, the total may be significant because many of the gases involved have low odor thresholds.

LUMBER MILLS

The largest industry in the area is the manufacture of lumber and wood products. The area has a total lumber production in excess of 250 million board feet per year as well as a 650-ton-per-day pulping operation. In all there are seven or eight lumber plants in addition to PFI, which conducts the largest lumbering operation in the area.

The waste produced from a log is about 50 percent of the original log; [15] more specifically, 10 percent is bark, 20 percent slabs, edging, and trimmings, and 20 percent shavings and sawdust.

For plants as large as PFI, the use of shavings and sawdust to make presto logs and the use of bark to make soil conditioner are profitable ways to dispose of these byproducts. Smaller lumbering mills normally burn their waste in large furnaces called Tepee burners. Some of the shavings are sold for bedding for cattle and some sawdust is sold for composting, but most of the waste is burned.

To estimate emissions from wood waste burning, an average density of 27 pounds per cubic foot [16] was assumed for the waste wood. On the basis of 1/12 cubic foot per board foot, the total weight of lumber produced per year was calculated. It was assumed that PFI used all shavings and sawdust to make presto logs, that all slabs, edgings, and trimmings were made into wood pulp, and that 50 percent of the bark was made into soil conditioner and the other 50 percent burned as waste. The remaining lumber mills in the area produce approximately 50 million board feet, or 20 percent of the total lumber produced. For saw mills it was assumed that sawdust and shavings were sold for bedding and composting. The remaining 30 percent, consisting of bark and slabs, was burned. For planing mills, it was assumed that 50 percent of all shavings and sawdust was sold and 50 percent was burned.

With the above assumptions, a total of 128,500 pounds per day was burned by PFI and a total of 262,500 pounds per day by the other lumber operations.

Emission factors were taken from the literature. [17] The computed emissions from wood waste burning show hydrocarbons and particulate matter to be the major pollutants (Table 3-11). Although wood waste burning can be considered a relatively minor source in the area, localized problems from smoke or wood particles may arise.

ASPHALT PLANT

One asphalt and gravel plant was reported in the area. This plant handles large quantities of gravel in drying and mixing operations and is a possible source of dust and smoke. The plant operates for 8 months each year, during which time approximately 56 thousand tons of gravel are processed.

Assumptions were made concerning the efficiency of the control equipment used by the plant, and the exhaust gases were assumed to contain 4 grains of dust per cubic foot at a temperature of 350°F. [18] On this basis, calculated dust emissions from the plant indicate that 1,712 pounds of dust is emitted to the atmosphere per working day. This dust is rather fine, with 76 percent of the particles less than 5 microns in diameter. This can cause a nuisance to receptors in the local area and contributes to reduction in visibility.

OTHER INDUSTRIAL OPERATIONS

In addition to the industrial processes already described, there are also stockyards, feed and grain mills, meat packing, and other miscellaneous operations. Information was not available to make estimates of emissions. It can be said in general that the total pollutants from such operations will be relatively small, but that the potential exists for localized dust and odor problems.

Table 3-11. ESTIMATED EMISSION FROM WOOD WASTE BURNING

Pollutant	Emission factor,[17] lb pollutant per 1,000 lb wood waste	Potlatch Forests Incorporated, lb/day	Other saw and planning mills,lb/day
Sulfur dioxide	0.08	10	21
Oxides of nitrogen	0.06	77	158
Hydrocarbons	10.0	1,285	2,625
Organic acids	0.2	26	53
Aldehydes	0.9	115	236
Particulates	1.3	167	341

FUEL USAGE

NATURAL GAS

Of all the fuels used in the area, both for home heating and industrial operations, natural gas is by far the "cleanest" from an air pollution standpoint.

The users of natural gas are 8 industrial operations, 348 commercial establishments, and 1,590 residences. [19] The residential and commercial users burn 146 million cubic feet, accounting for 3.6 percent of the total gas usage. The industrial users, not including PFI, account for 88 million cubic feet, or 1.3 percent of the total. The remaining 95.1 percent is used by PFI and totals 6,270 million cubic feet a year. In calculations of emissions, natural gas was assumed to have an approximate density of 0.048 pound per cubic foot and a sulfur content of 0.4 grain per hundred cubic feet.

Although natural gas combustion is clean compared with coal and oil, the large volume burned partially compensates for the low emission factors and results in atmospheric pollution (Table 3-12). The major pollutants emitted by natural gas combustion are oxides of nitrogen, aldehydes, and organic acids. For each of the above pollutants, natural gas is a significant contributor to the total emission in the area. As one would expect, because of the tremendous volume of natural gas burned each day, PFI is the most significant source of emission from the combustion of this fuel.

COAL, OIL, AND PRESTO LOGS

Coal and oil are predominantly used for home heating in the Lewiston Orchards area. Both Lewiston and Clarkston have natural gas, and the majority of homes and businesses use gas as a source of heat. Presto log usage is not localized; most people in the area use them as a secondary source of heat. Compared to natural gas, coal and oil are relatively "dirty" sources of heat since they release more atmospheric contaminants. Coal is worse than oil, with high emissions of oxides of sulfur, hydrocarbons, and particulates. Oil has relatively high emissions of sulfur oxides, nitrogen oxides, and particulates. The total emissions depend on the amount and the chemical and physical properties of coal and oil used.

Coal, used primarily in the Lewiston Orchards area, has a sulfur content of only 0.6 percent [21] by weight, which minimizes the amount of sulfur oxides emitted to the air. Total coal usage is estimated at 7,000 tons per year. [22] The heating season in the area was assumed to be 150 days long, and it was further assumed that the 7,000 tons of coal were consumed during the heating season. Estimated emissions from the use of coal are given in Table 3-13.

Sales of Number 1 and 2 fuel oils, used primarily for home heating, totaled 5.3 million gallons during the 5-month heating season. [23] Residual oil, which is used in large heating plants such as schools and hospitals, was consumed at the rate of 1 million gallons during the heating season. [23] The sulfur content of these oils was estimated as 0.5 percent by weight, and density of the oils was estimated as 7.29 pounds per gallon.

Presto log usage totaled 24,000 tons for the heating season [25] and was assumed to be distributed over the whole area rather than concentrated in Lewiston Orchards. To estimate emissions from combustion

Table 3-12. ESTIMATED EMISSIONS FROM COMBUSTION OF NATURAL GAS [a]

Pollutant	Gas consumer					Total Emissions, lb/day
	Residential and commercial (3.6 percent) [b]		Industrial			
			All industry except P.F.I. (1.3 percent)[b]		Potlatch Forests Incorporated (95.1 percent) [b]	
	Emission factor, lb/1,000 lb	Emission during heating season, lb/day [c]	Emission factor, lb/1,000 lb	Emission, lb/day	Emission, lb/day	
Sulfur oxides [d]	0.028	2.3	0.028	<1	24	27
Nitrogen oxides	2.4	80	4.5	50	3,680	3,810
Carbon monoxide	0.008	<1	0.008	Neg	7	7
Aldehydes	Neg	Neg	0.05	0.5	34	34
Other organic gases	Neg	Neg	0.1	1.0	86	87
Particulates	0.4	12	0.37	4	300	316

[a] Reference 20.

[b] Percent of total natural gas consumption.

[c] Assume 150 heating days per year.

[d] Assume sulfur content of natural gas as 0.4 grain/100 ft^3.

Table 3-13. ESTIMATED EMISSIONS FROM COMBUSTION OF FUELS FOR RESIDENTIAL AND COMMERCIAL HEATING [a]

Pollutant	Fuel						Total emissions during heating season, lb/day
	Coal [b] (7,000 tons per year)		Oil (6.3 million gallons per year)		Presto logs (24,000 tons per year)		
	Emission factor, lb pollutant per 1,000 lb fuel	Emissions during heating season, lb/day	Emission factor,[c] lb pollutant per 1,000 lb fuel	Emissions during heating season, lb/day	Emission factor,[d] lb pollutant per 1,000 lb fuel	Emissions during heating season, lb/day	
Oxides of sulfur [e] (as sulfur dioxide)	11.0	1,026	9.9	2,950	0.08	24	4,000
Oxides of nitrogen (as nitrogen dioxide)	0.2	19	9.0	2,682	0.6	180	2,881
Hydrocarbons and other organics	5.0	467	0.5	149	5.0	1,500	2,116
Aldehydes (as formaldehyde)	f	f	0.25	75	0.45	135	210
Particulates	12.0	1,120	1.5	447	0.65	195	1,762

[a] Emissions calculated on basis of 150-day heating season.

[b] Assumed to be residential use - heating and cooking.

[c] Reference 24.

[d] Reference 17.

[e] Sulfur contents: coal, 0.6%; oil, 0.5%; presto logs, 0.004%.

[f] Included with hydrocarbon.

of this fuel, the sulfur content was assumed to be that of pine wood, and emission factors determined for burning waste wood were applied.

The major contaminants released to the air from the combustion of oil, coal, and presto logs are seasonal, localized, and consist mainly of sulfur and nitrogen oxides, hydrocarbons, and particulate material (Table 3-13.)

FUEL USED IN MOTOR VEHICLES

Consumption of gasoline and diesel fuel in the area is estimated as 8 million gallons a year for gasoline [23] and 20 thousand for diesel fuel. [26] The major pollutants from gasoline usage are hydrocarbons, oxides of nitrogen, and carbon monoxide. Compared with the emissions from gasoline engines, diesel engine emissions are lower in total hydrocarbons and oxides of nitrogen, and higher in particulates.

Table 3-14 presents the emission factors used to calculate the emissions of various pollutants and the results of the calculations. Emissions from vehicle exhaust would be most concentrated in the downtown area during peak traffic hours. Hydrocarbons and oxides of nitrogen are important emissions since they enter in the so-called photochemical smog reaction. Urban area carbon monoxide is also significant since this toxic gas can reach rather high levels during heavy traffic hours.

REFUSE DISPOSAL

There are two major refuse disposal sites in the area, one in Lewiston Orchards and one north of Clarkston near the river. Backyard burning is permitted in both Lewiston and Clarkston and in unincorporated Lewiston Orchards and Clarkston Heights.

In Lewiston refuse is collected daily from restaurants and businesses and weekly from residences by a private contractor. All households and businesses are required to subscribe to the refuse collection service. Backyard burning is permitted in Lewiston, and approximately 20 percent of all refuse is disposed of in this manner. [27] The bulk of the refuse, 80 percent, is hauled to a sanitary landfill operation, and little if any burning takes place.

Lewiston Orchards has voluntary refuse collection, and residents who do not avail themselves may haul their own refuse or burn it in the backyard. It is estimated that 50 percent of the refuse in Lewiston Orchards is burned by residents and the remainder hauled to the landfill.

Clarkston provides a mandatory refuse collection service, but subscription to this service is not adequately enforced. [28] Refuse is collected three times weekly from restaurants and businesses and

Table 3-14. EMISSIONS FROM MOTOR VEHICLES

Pollutant	Gasoline factor,[a] lb/gal	Diesel factor,[b] lb/gal	Emissions from gasoline, lb/day	Emissions from diesel fuel, lb/day	Total, lb/day
Total hydrocarbons	0.300	0.715	6,580	39	6,619
Oxides of nitrogen	0.100	0.222	2,195	12	2,207
Carbon monoxide	3.0	-	65,800	-	65,800
Sulfur dioxide	0.007	0.015	154	1	155
Aldehydes	0.005	0.016	110	1	111
Organic acids	0.002	0.031	44	2	46
Ammonia	0.002	-	44	-	44
Particulates	0.0003	0.086	6.5	5	12

[a] Reference 20.
[b] Reference 17.

once weekly from residences. It is estimated that 20 percent of the refuse in Clarkston is burned in backyard incinerators by residents and that the remaining 80 percent is collected by the City. In Clarkston rubbish burns more or less continually with the consequent emission of odors, smoke, and particulate matter. Approximately 1,000 householders immediately adjacent to the City of Clarkston have a voluntary collection program that has 150 subscribers. The remainder of the householders burn their refuse in incinerators.

Clarkston Heights has no refuse collection, and approximately 80 percent of all refuse is burned by residents and the remainder hauled to the Clarkston dump.

The per capita production of rubbish is estimated as 1,400 pounds per person per year; [29] the combustible content of all refuse is assumed to be 70 percent. Population estimates were based on the 1960 census figures. [30]

Table 3-15 presents the calculated emissions from each source as well as the emission factors used. This table does not include an estimation of the odor problem from waste burning. Odors can, however, be a considerable problem when large amounts of garbage are burned, and an attempt has been made to evaluate the problem in the odor survey section of this report. The most important emissions from refuse burning are carbon monoxide and particulates. Combustion of refuse does not constitute a major source of pollution, but at times may be the cause of local irritation and complaint.

Table 3-15. ESTIMATED EMISSIONS FROM COMBUSTION OF REFUSE

Pollutant	Emission factor,[a] lb per lb burned	Emissions, lb/day				
		Lewiston	Lewiston Orchards	Clarkston, Clarkston Heights, and adjacent area		Total
		Backyard burning	Backyard burning	Backyard burning	Dump burning	
Oxides of sulfur (as sulfur dioxide)	0.0015	10	20	17	21	68
Oxides of nitrogen (as nitrogen dioxide)	0.002	14	26	22	28	90
Total hydrocarbons	0.003	20	39	33	43	135
Aldehydes (as formaldehyde)	0.005	34	65	55	71	225
Other organic gases	0.004	28	52	44	57	181
Carbon monoxide	0.02	140	260	220	284	904
Particulates	0.011	76	143	121	156	496

[a] Reference 20.

SUMMARY

An estimate of major air contaminant emissions for the area was made from information provided by the communities and industries in the area. No stack sampling was done. All estimates were based on information from the literature and other sources.

The major contributor of hydrogen sulfide and other malodorous organic gases is the kraft pulp mill. In addition, the pulp mill contributes about 77 percent of the estimated gaseous emissions and about 82 percent of the estimated particulate emissions. It also contributes an estimated 4,640 tons of water vapor each day to the atmosphere. This is thought to have a significant effect on the humidity in the valley under certain meteorological conditions. The major gaseous emission from the pulp mill is the "combustible" from three recovery furnaces and three lime kilns. This combustible probably consists of carbon monoxide and partially oxidized organic compounds.

The pulp mill has installed many control devices, but the recovery furnaces and kilns may, from time to time, permit a substantial emission of odorous compounds to the atmosphere. A sulfate pulp mill also has innumerable small sources of odor emissions that in total may constitute a difficult problem.

Emissions from other industrial operations are relatively small. Home heating is the largest source of sulfur oxides, while transportation (gasoline engine exhaust) contributes a substantial amount of carbon monoxide to the atmosphere. Refuse disposal is a relatively minor source of air contamination on a weight basis, but the odor produced by burning garbage and refuse can cause local nuisances.

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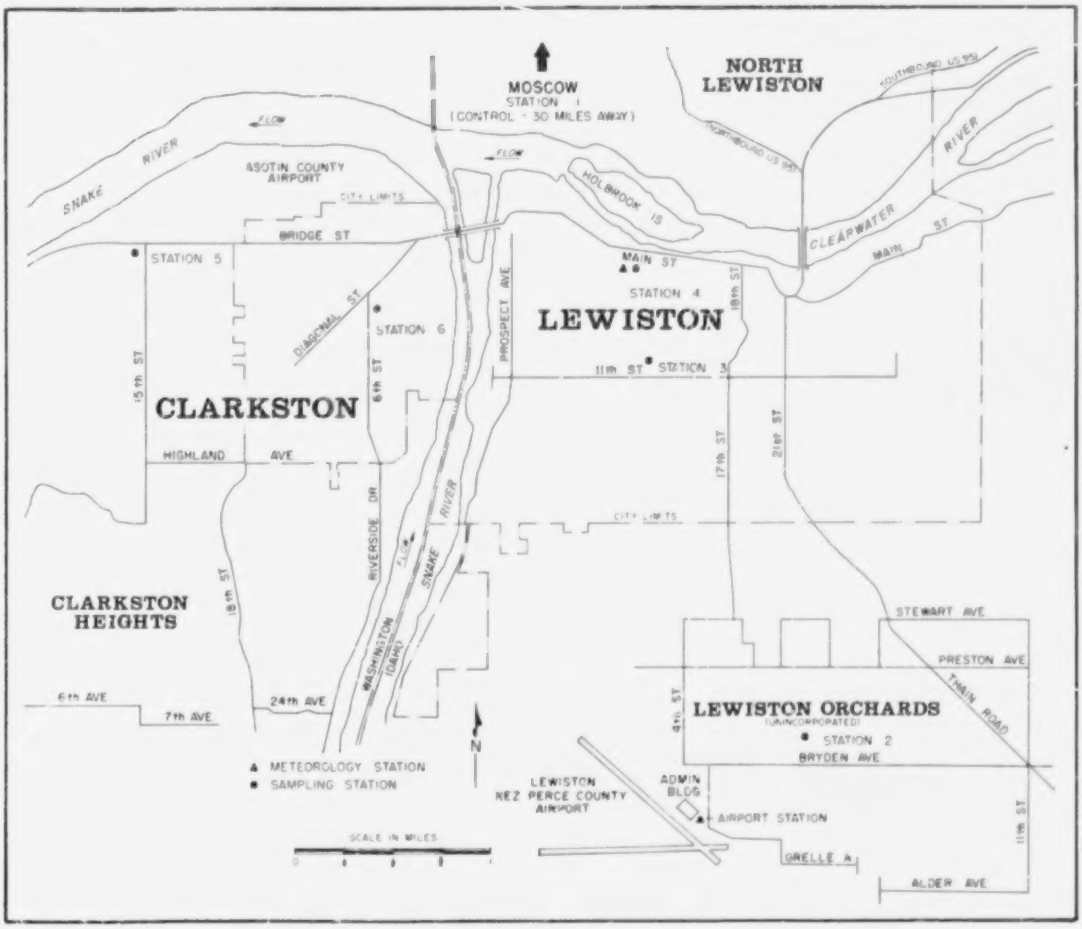
CHAPTER IV. EVALUATION OF AIR QUALITY

DESCRIPTION OF SAMPLING STATION

GENERAL CONSIDERATIONS

In this study seven sampling stations were established (Table 4-1 and Figures 4-1 through 4-6). Six were set up with AISI hydrogen sulfide tape samplers and silver and paint panels. The seventh was a meteorological station on the post office building in Lewiston. Here wind speed, wind direction, temperature, and relative humidity were measured. In addition to this basic equipment, one station in Clarkston (the City Hall fire station site) had a high-volume air sampler and gas analysis equipment for hydrogen sulfide and sulfur dioxide. Two others had high-volume samplers - the courthouse station in Lewiston and the control station at the Waterworks in Moscow, Idaho. The post office in Lewiston has been used as a reference point for evaluation under the assumption it represented the valley floor.



MOSCOW
STATION 1
(CONTROL - 30 MILES AWAY)
NORTH LEWISTON
SOUTHBOUND US 95
NORTHBOUND US 95
SNAKE RIVER
FLOW
FLOW
ASOTIN COUNTY AIRPORT
CITY LIMITS
HOLBROOK IS
CLEARWATER RIVER
MAIN ST
BRIDGE ST
STATION 5
MAIN ST
STATION 4
18th ST
DIAGONAL ST
STATION 6
PROSPECT AVE
LEWISTON
15th ST
6th ST
11th ST
STATION 3
CLARKSTON
HIGHLAND AVE
17th ST
21st ST
RIVERSIDE DR
FLOW
SNAKE RIVER
CITY LIMITS
CLARKSTON HEIGHTS
18th ST
STEWART AVE
WASHINGTON
IDAHO
PRESTON AVE
THAIN ROAD
6th AVE
7th AVE
24th AVE
4th ST
LEWISTON ORCHARDS
(UNINCORPORATED)
STATION 2
BRYDEN AVE
N
METEOROLOGY STATION
SAMPLING STATION
LEWISTON NEZ PERCE COUNTY AIRPORT
ADMIN BLDG
AIRPORT STATION
11th ST
SCALE IN MILES
0
1
GRELLE A
ALDER AVE

Figure 4-1. Station location map.

Table 4-1. DATA ON SAMPLING STATIONS (Continued)

Name and location of sampling stations	Height above valley, ft	Height above sea level, ft	Type of area	Observational quality	Potential pollution sources nearby	Type of equipment	Remarks
5. West Clarkston. In Highway Department utility shed.	13	748	Residential and rural.	Only obstructions were a large storage building to the west and several tall houses to east. Open pasture north and south.	Residential space heating, auto exhausts.	H_2S tape sampler inside shed, 8 paint samples on outside walls, silver samples near the tape sample.	Teflon probe extended to outside air 10 ft above ground.
6. Clarkston Commercial. In Clarkston City Hall.	84	819	Commercial and residential.	No tall obstacles. Parking and vacant lots extend 100 to 300 ft in three directions.	Commercial smokestacks, auto exhausts, windborne ground dust.	Three H_2S tape samplers, inside the fire station. Two sequential samplers, for H_2S and SO_2 for three 2-week periods. Eight paint samples on outside walls. High-volume particulate sampler on roof.	Inlet line to one sampler submerged in constant temperature water bath. Teflon probe extended to outside air, 10 ft above ground.
7. Lewiston Meteorological Station. In Lewiston Post Office building.	0	7355	Commercial and residential. Some light industry.	Little obstruction. Two-story building to south, and other 2-story buildings to NW and SE, several hundred feet away.	Commercial and residential smokestacks, auto exhausts, some light industry to the north.	Instruments for recording wind speed, wind directions, relative humidity and temperature.	Instruments located on roof. Wind speed, wind direction, reltive humidity, temperature recorded continuously here Jan. - Apr. 1962. Wind instrument on mast 18 ft above roof and 46-1/2 ft above ground. Temperature and relative humidity recorder 33-1/2 ft above ground. Station simulates the old Weather Bureau Station that was here until 1948.

Table 4-1. DATA ON SAMPLING STATIONS

Name and location of sampling stations	Height above valley, ft	Height above sea level, ft	Type of area	Observational quality	Potential pollution sources nearby	Type of equipment	Remarks
1. Moscow, Idaho. In water pumping station.	1,965	2,700	Residential and commercial.	No obstructions, except for several 2-story buildings some distance away.	Space heating and auto exhausts. No major source.	H_2S tape sampler on 1st floor, 8 paint samples on tower on roof, silver samples atop tape sampler. High-volume particulate sampler on roof for three 2-week periods.	Used as the control station because of nonindustrial area. Roof 25 ft above ground. Teflon probe extended to outside air.
2. Lewiston-Orchards. In Warmer Grade School building.	659	1,394	Residential, with small gardens and fields.	Bordered on west and south by playgrounds, and on north and east by roads and residence.	Residential heating, auto exhausts, blowing dust. No major source.	H_2S tape sampler indoors, 8 paint samples on exterior of building, silver samples inside.	Teflon probe extended to outside air, 12 ft above ground.
3. Lewiston Residential. In old Lewiston Junior High School.	135	870	Residential, at intermediate elevation between Lewiston Orchards and Lewiston Commercial.	No obstructions. Large playfield south of building.	No major source. Residential heating, auto exhaust. Traffic east of station only.	H_2S sampler (AISI) on 2nd floor, NE corner, 8 paint samples attached to outside walls. Silver samples indoors.	Streets north and west of building blocked off. Teflon probe extended to outside air, 35 ft above ground.
4. Lewiston Commercial. In Lewiston Courthouse.	0	735	Commercial and light industrial.	Minor obstacles. Some 3-story buildings to north and south.	Smokestack of courthouse, feed mill to NW, auto exhaust, other heating smokestacks.	H_2S tape sampler on 3rd floor on north side, 8 paint samples on outside walls. Silver samples atop tape sampler. High-volume particulate sampler on roof, for three 2-week periods.	Teflon probe extended to outside air, 35 ft above ground. Roof 45 ft above ground.

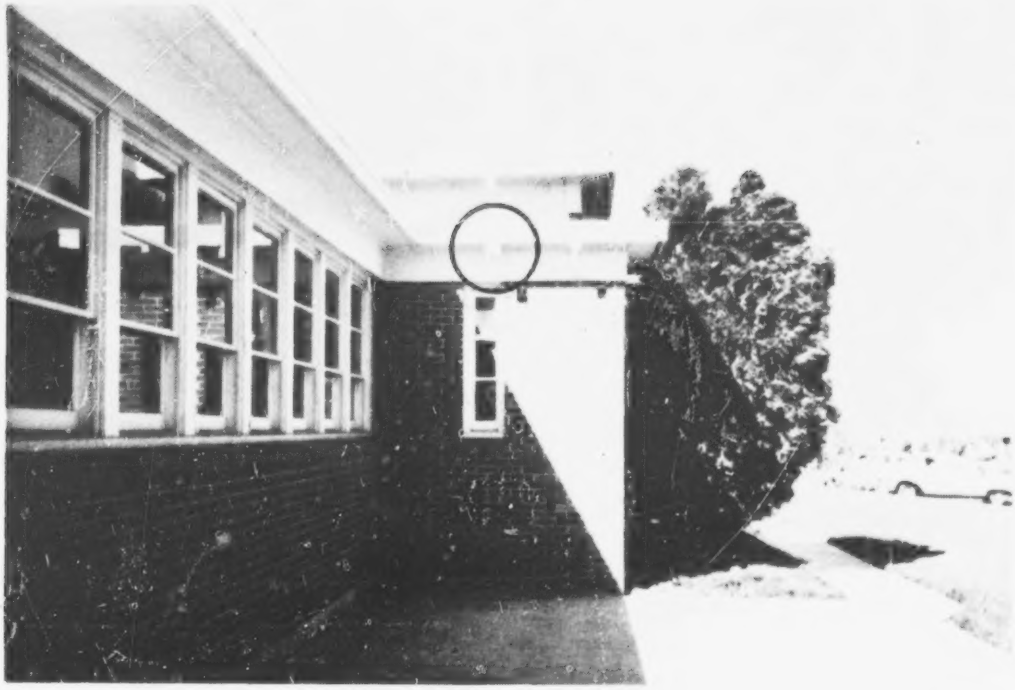


Figure 4-2. Lewiston Orchards sampling station. View of Warner Grade School shows sample inlet tube.

ATMOSPHERIC PARTICULATE MATTER

GENERAL

Twenty-four-hour atmospheric particulate samples were collected for 14 consecutive days during each of the study periods in November 1961, January 1962, and April 1962, at three permanent sampling sites in Lewiston, Idaho; Clarkston, Washington; and Moscow, Idaho. Particulates were separated by filtration through 8- by 10-inch glass fiber filters held in high-volume air samplers and were collected at flow rates of 40 to 60 cubic feet of air per minute. The variation in flow rate depended upon the nature and amount of particulates deposited. Sample filters were changed daily between 1500 and 1700 hours, and the measurements were dated and recorded as of the day sampling ended. The samples were analyzed for total particulates, and for sulfate, sodium, and calcium content.

RESULTS

Atmospheric particulate loadings, reported in micrograms of dust per cubic meter of air, at both the valley sites (Lewiston and Clarkston)

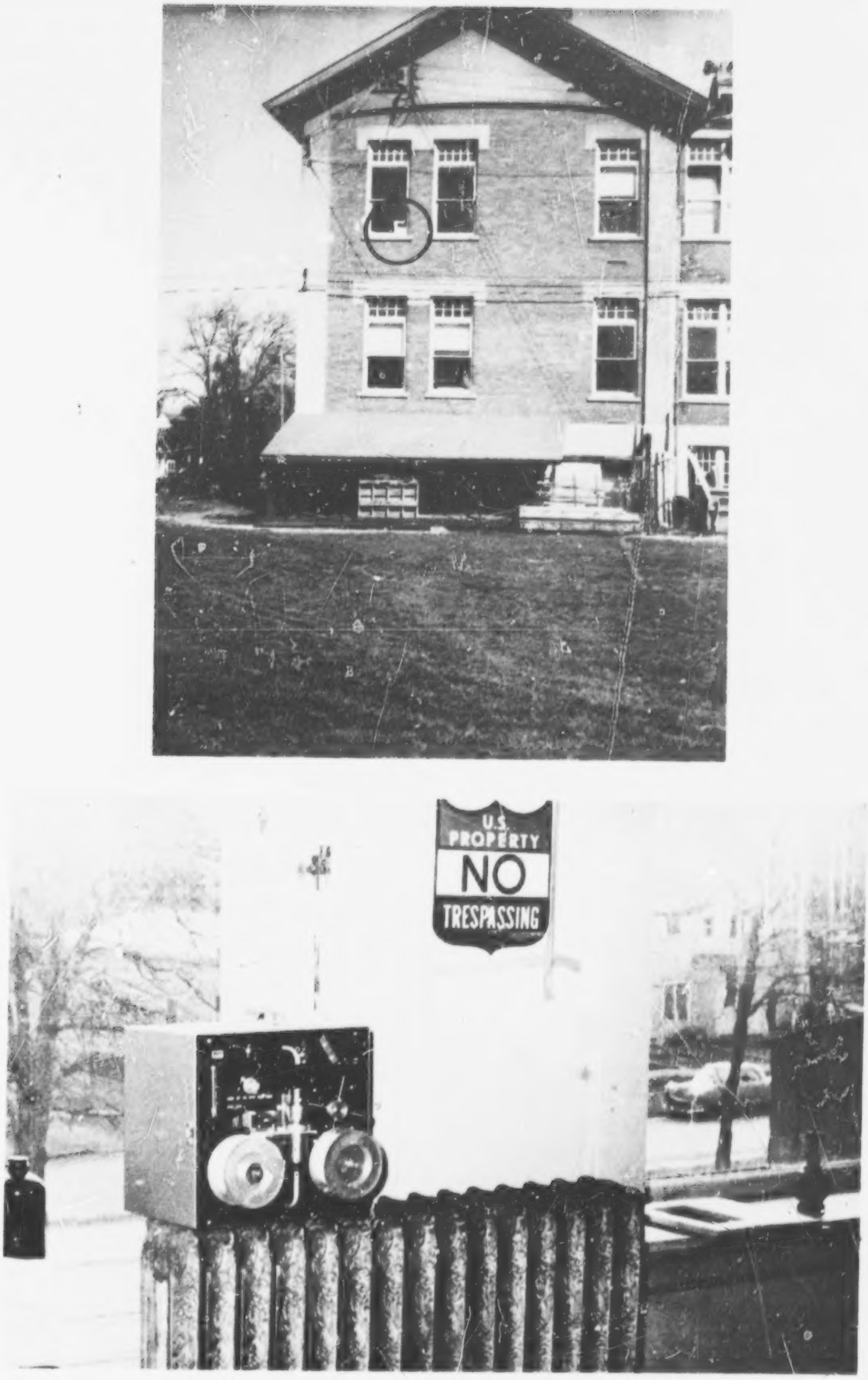

U.S. PROPERTY
NO
TRESPASSING

Figure 4-3. Lewiston residential sampling station. Exterior and interior views of old Junior High School show AISI sampler and silver sample in upstairs window.

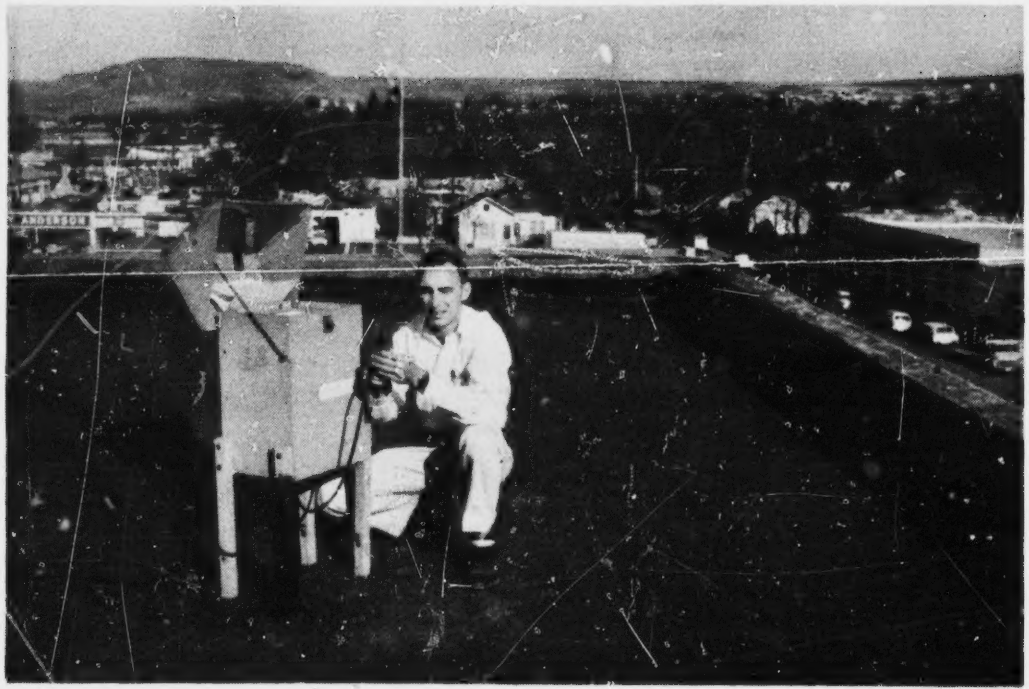


Figure 4-4. Lewiston commercial sampling station No. 4.
Hi-vol sampler on roof of Lewiston Courthouse.

and the mountain plateau, nonindustrialized control site (Moscow) were lowest during January (Table 4-2). Highest average particulate loadings occurred in Moscow and Clarkston during April. During November and January particulate loadings were generally higher in Lewiston than in Clarkston and lowest in Moscow. It can be observed from Figure 4-7 that particulate loading often varied directly with wind speed and inversely with degree-days.

Meteorological data for the valley sites were obtained at a weather station in Lewiston, established for this study, and at the Nez-Perce Airport weather station. Weather data for Moscow, obtained at the Pullman-Moscow Airport, were available only during the April study period. Estimated meteorological data for November and January are used for the purpose of comparison. From topographical features and previous records, it is reasonable to assume that during the study periods wind speeds were generally higher and temperature generally lower in Moscow than in the valley. The positive relationship between wind speed and particulate loading indicates that the total air-borne particulate content is greatly influenced by wind entrainment of solid material from the ground. Frozen ground conditions and snow cover minimized atmospheric particulate concentrations during January.

Table 4-2. ATMOSPHERIC PARTICULATE CONCENTRATIONS AND METEOROLOGICAL PARAMETERS

Date	Lewiston particulate concentration, μg/m^3 [a]			Clarkston particulate concentration, μg/m^3 [a]			Average wind speed, [b] mph	Total degree-days [c]	Moscow particulate concentration, μg/m^3 [a]			Average wind speed, [c] mph	Total degree-days [c]
	Max.	Min.	Avg	Max.	Min.	Avg			Max.	Min.	Avg		
November 6-19	282	96	183	272	57	155	5	401	287	61	132	d	d
January 9-22	160	46	118	120	63	85	4	586	165	30	66	d	d
April 16-29	328	40	147	459	38	164	6	137	1,047	80	235	9	191

[a] Concentration is expressed as micrograms of dust per cubic meter of air.

[b] Measurement obtained from weather station at Nez-Perce Airport in November and from special weather station in Lewiston during January and April.

[c] Measurements obtained from weather station at Pullman-Moscow Airport.

[d] Data are not available.

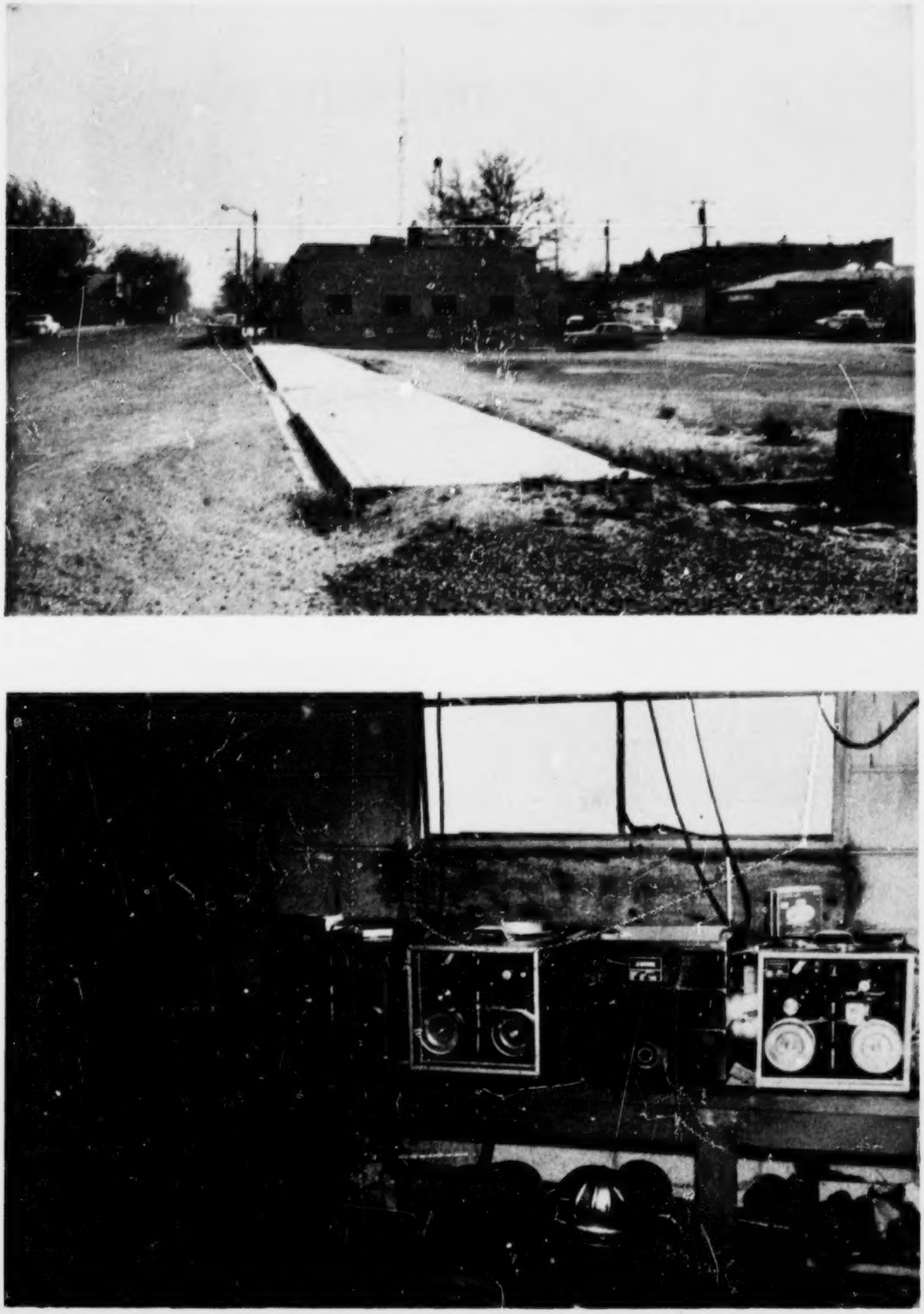


Figure 4-5A. Clarkston commercial sampling station No. 6, Clarkston City Hall and Fire Station. Samplers inside Fire Station included controlled-temperature, standard, and Idaho State Health Department AISI tape samplers.

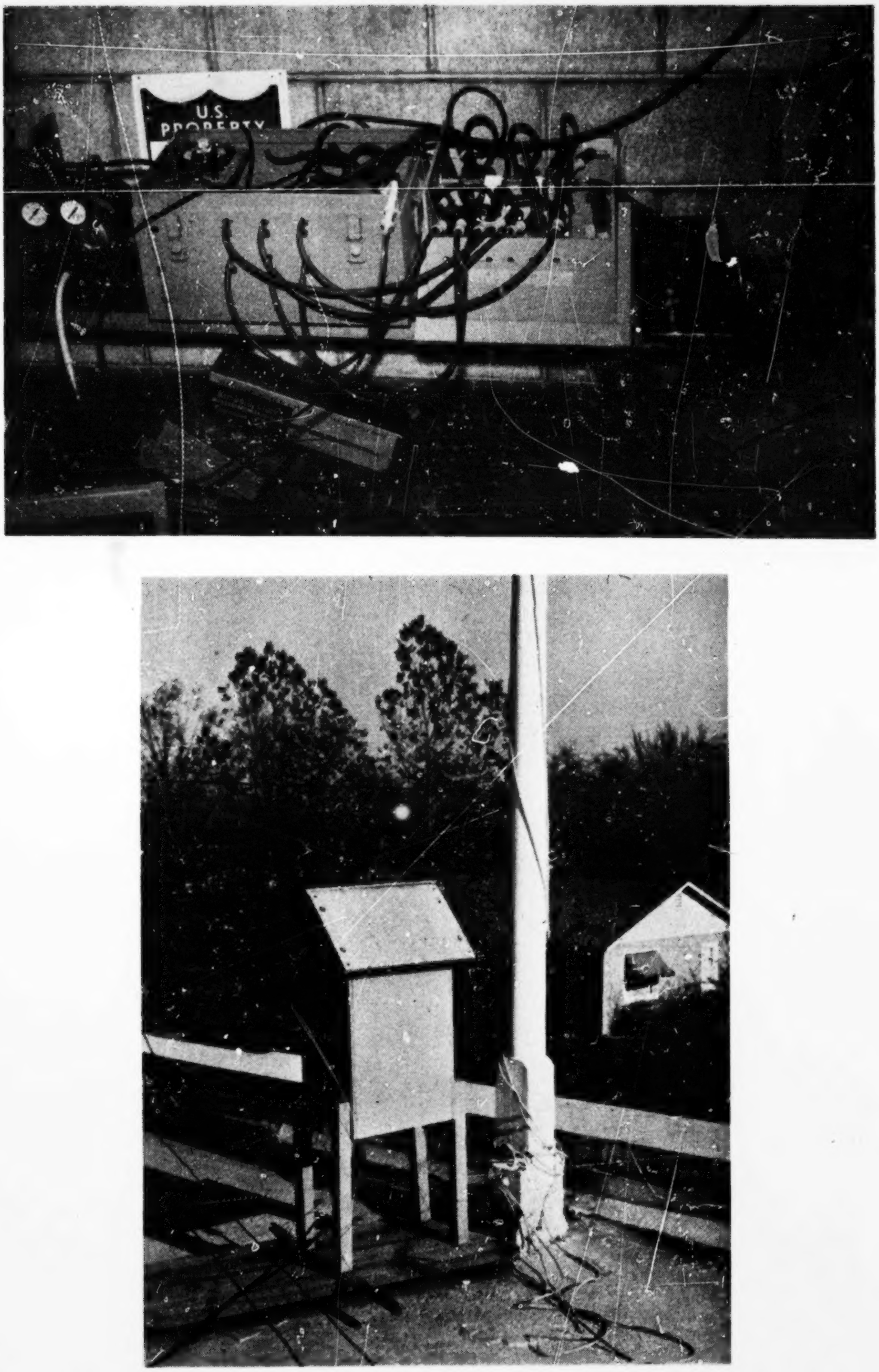


Figure 4-5B. Clarkston commercial sampling station No. 6. Samplers inside Fire Station included Gelman sequential gas sampling apparatus.
Hi-vol sampler was on top of Fire Station.

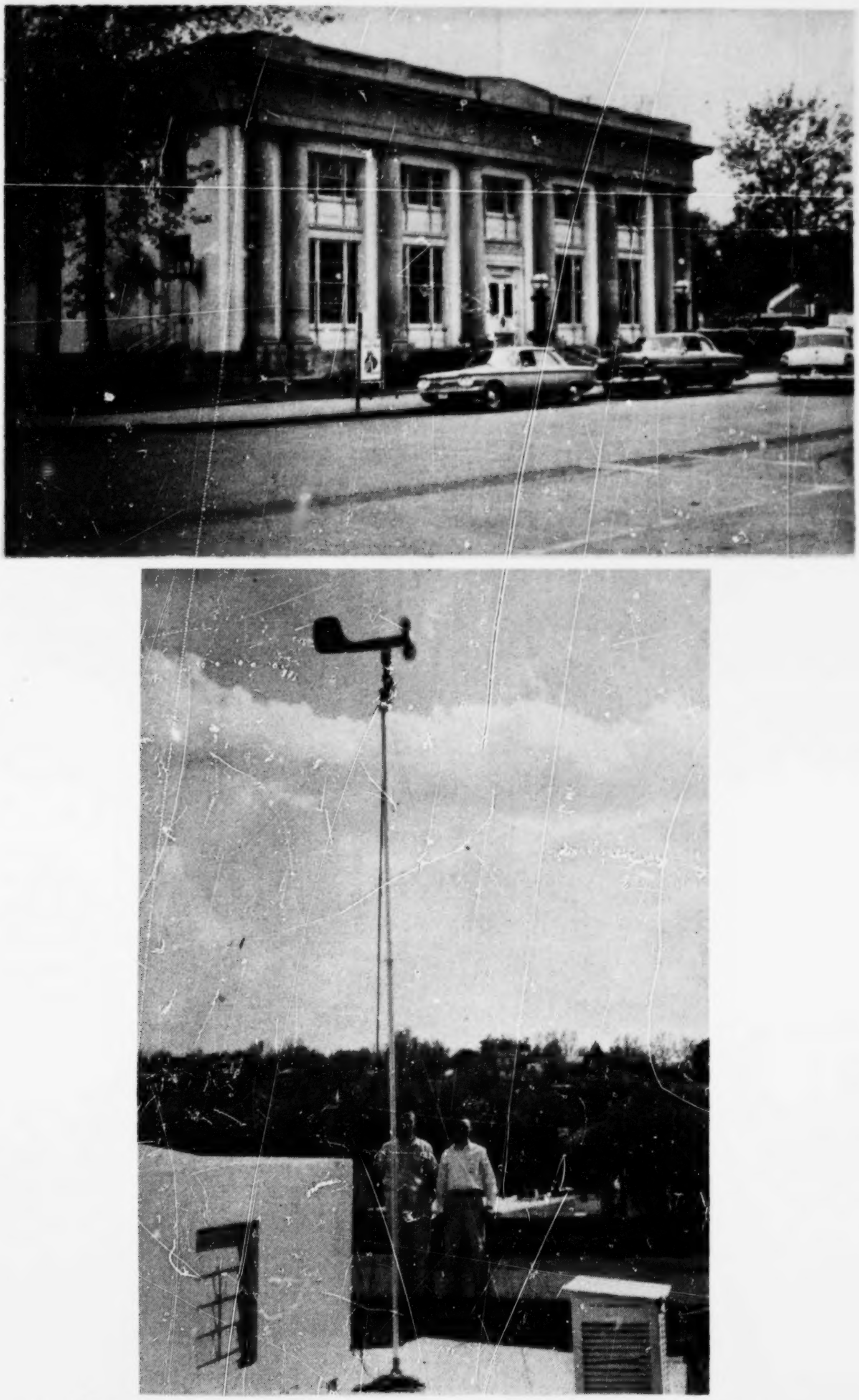


Figure 4-6. Post Office meteorological station. View of roof shows aerovane.

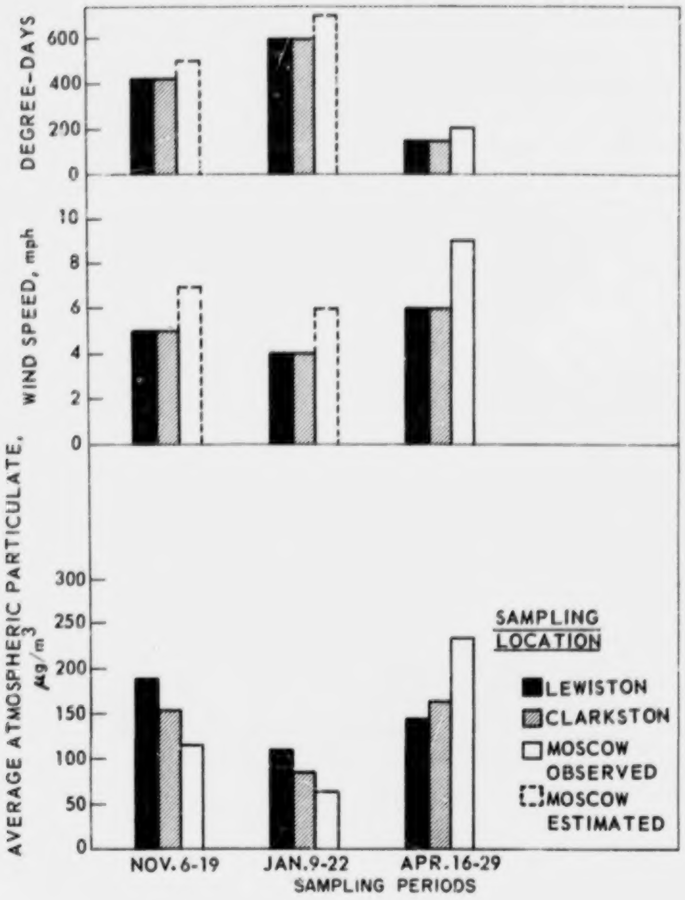


Figure 4-7. Comparison of atmospheric particulate loading with wind speed and degree-days.

Microscopic examination of several samples revealed large quantities of inorganic dusts, such as quartz and gypsum, particularly in samples collected during April and to a lesser extent in November.

Particles derived from the incomplete combustion of wood and other combustible material were also observed. The number of these particles was greater during January than November, which agrees with the amount of fuel used for heating. The number was lowest in April. Total atmospheric particulate loading varied inversely with degree-days, however, indicating that emissions of particulates in the atmosphere from the combustion of fuels for heating make only a minor contribution to over-all pollution, which leads in turn to the conclusion that the atmospheric particulates originate largely from natural and industrial sources.

The percentage compositions of sulfates and sodium in the particulate samples were significantly higher in Lewiston and Clarkston than in Moscow (Table 4-3). Calcium compositions did not vary significantly, indicating natural sources such as wind entrainment of ground dusts for the presence of calcium in samples. Sodium oxide and sulfate are discharged in large quantities in the black liquor recovery furnace process of a sulfate process pulp mill without recovery equipment or with poor recovery equipment. Large quantities of sulfate are also discharged in solid and liquid fuel-burning operations, but emissions from fuel used for heating did not contribute to a major extent to the total air pollution.

CONCLUSIONS REGARDING PARTICULATES

The relationship of particulate air pollution and meteorological data indicates that, during November 1961 and January and April 1962, the major sources of atmospheric particulates were industrial emissions and natural ground dusts entrained by wind. Analysis of the composition of particulates indicates that industrial processes resulting in discharge of sodium and sulfate compounds contribute substantially to the total atmospheric particulate pollution in Lewiston and in Clarkston.

Table 4-3. AVERAGE COMPOSITION OF ATMOSPHERIC PARTICULATES SAMPLED [a]

Location	Percent		
	Sulfates	Sodium	Calcium
Lewiston	21.7	3.5	2.0
Clarkston	21.4	3.0	3.0
Moscow	14.5	1.3	2.9

[a] Based on analysis of 40 samples and 40 determinations of each constituent.

VISIBILITY

Reduction of visibility is one of the most obvious and easily detected manifestations of atmospheric pollution. Reduction of visibility is caused by two physical mechanisms, both related to the presence of pollutant aerosols in the air: light scattering and light absorption. Light is scattered when it is refracted by aerosols in the atmosphere. Greatest scattering occurs when the wave length of the incident light is approximately equal to the diameter of the aerosols. Absorption of light is generally caused by the larger sized aerosols and does not affect visibility as greatly as scattering.

The most common visibility-reducing agents are particulate matter and water vapor in the form of fog. Many types of particulates occur naturally, but by far the most are man-made fly-ash, industrial dust, etc. Studies have shown that fog can be induced by the presence of particulates. Particulates provide convenient condensation nuclei for water vapor in the atmosphere.

Although reduction in visibility can indicate the presence of atmospheric pollution, it is by no means the most reliable index. Many pollutants, such as gases, do not reduce visibility, and not all reductions in visibility are caused by atmospheric pollutants.

METHODOLOGY

Visibility Observations

Observations of visibility were made from the roof of the Lewiston Post Office Building each morning and afternoon from November 8, 1961, to April 30, 1962. Prominent objects in each direction were chosen as markers and their distances determined. A map was prepared with concentric circles around the Post Office showing the direction and distance of each marker (Figure 4-8). Each observation included the distance of the farthest marker visible in each direction.

The topography of the Lewiston area does not lend itself well to this method of visibility observations. Because the observation point is in a valley surrounded by high ground, the distance to the farthest marker in each direction varied from 1/4 to 1 mile. These distances are too short for an optimum visibility observation program.

Airport Smoke Observations

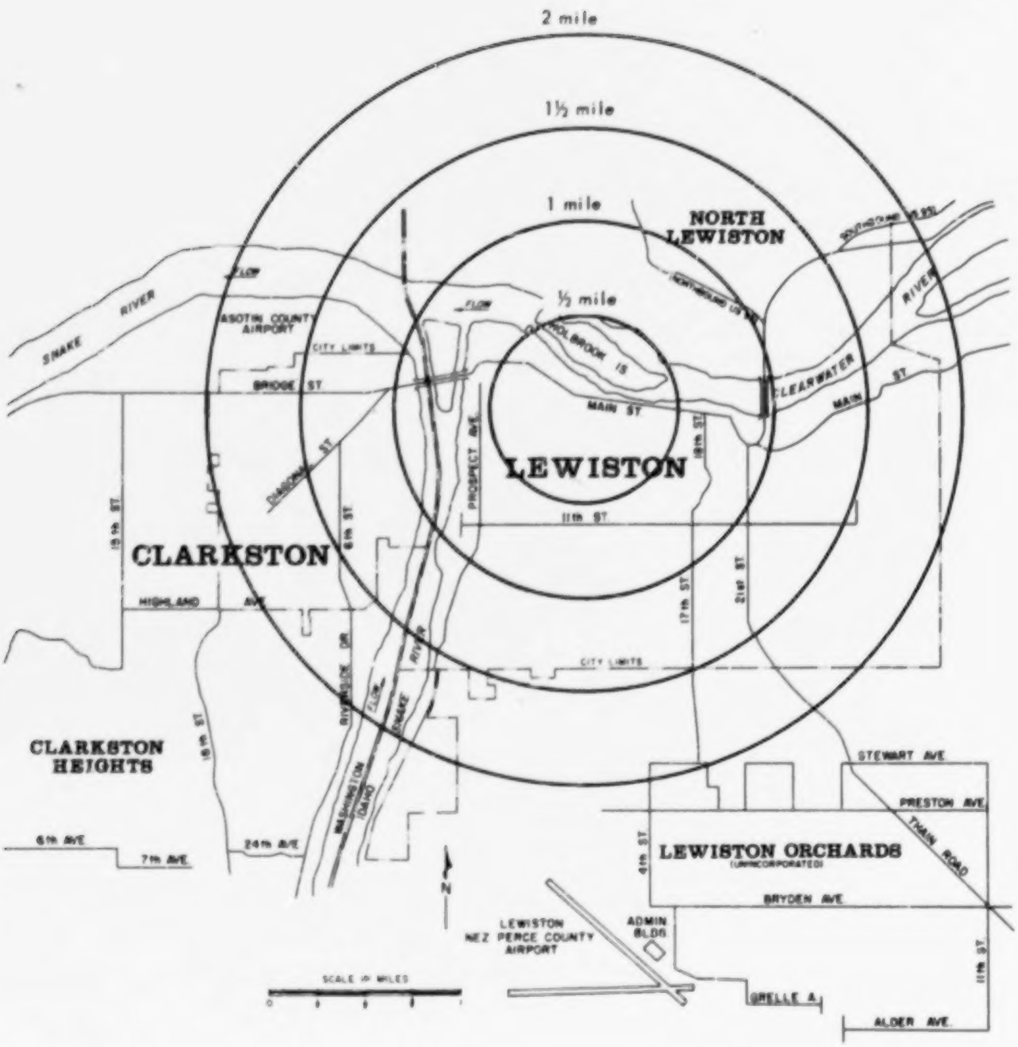
Observations of smoke in the valley made by the Weather Bureau station personnel at the Lewiston Airport from July 1943 through October 1959 have also been used to analyze the incidence of visibility-reducing pollution.

Photographs

Photographs were taken in a northerly direction from an elevation of 1,250 feet approximately 1-1/2 miles south of Lewiston, from November 16, 1931, to February 21, 1962, to provide a visual record of the incidence and severity of pollution in the valley.

Airport and City Meteorological Data

Data from the previously described meteorological stations at the Lewiston Airport and the Lewiston Post Office were used in the analysis of the airport smoke reports to relate the incidence of smoke in the valley with pertinent weather data such as relative humidity, wind direction, etc.


2 mile
1½ mile
1 mile
½ mile
NORTH LEWISTON
SNAKE RIVER
FLOW
ASOTIN COUNTY AIRPORT
CITY LIMITS
BRIDGE ST
MAIN ST
CLEARWATER RIVER
LEWISTON
PROSPECT AVE
18th ST
11th ST
DIAGONAL ST
19th ST
6th ST
CLARKSTON
HIGHLAND AVE
RIVERSIDE DR
SNAKE RIVER
17th ST
21st ST
CITY LIMITS
CLARKSTON HEIGHTS
16th ST
WASHINGTON
IDAHO
STEWART AVE
PRESTON AVE
THAIN ROAD
6th AVE
7th AVE
24th AVE
4th ST
LEWISTON ORCHARDS
(UNINCORPORATED)
BRYDEN AVE
N
LEWISTON NEZ PERCE COUNTY AIRPORT
ADMIN BLDG
11th ST
SCALE IN MILES
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1
GRELLE A
ALDER AVE

Figure 4-8. Visibility map of Lewiston–Clarkston area.

VISIBILITY IN THE VALLEY

Past History

A review of the smoke reports by the Lewiston Airport Weather Bureau Station shows that the incidence of smoke in the valley in 1959 was about 3-1/2 times what it was in 1948 (Figure 4-9). Where smoke was reported an average of 5 days each month in 1948, the average was 18 in 1959. In February 1959, smoke was reported 26 days.

Figure 4-10 shows the average monthly variation of smoky days for the period from 1948-1959. As can be expected, the incidence of smoky days was greatest during the winter months when inversion conditions were most persistent.

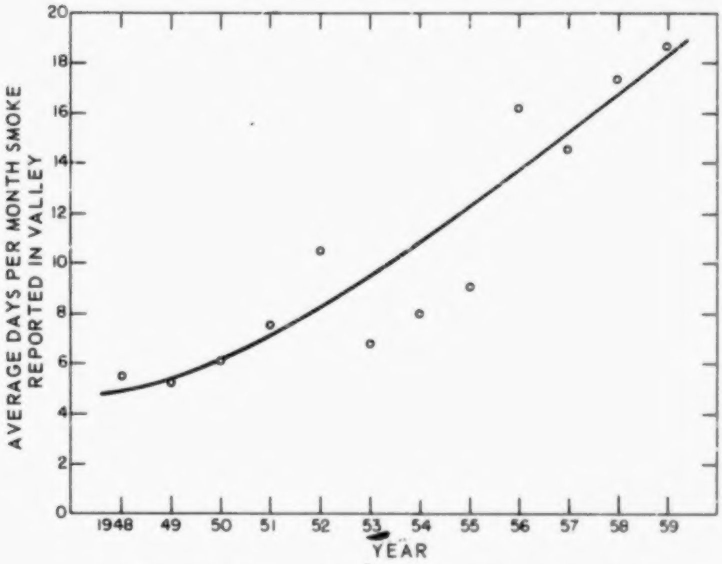


Figure 4-9. Annual airport observation of smoke over the city, 1948–1959.

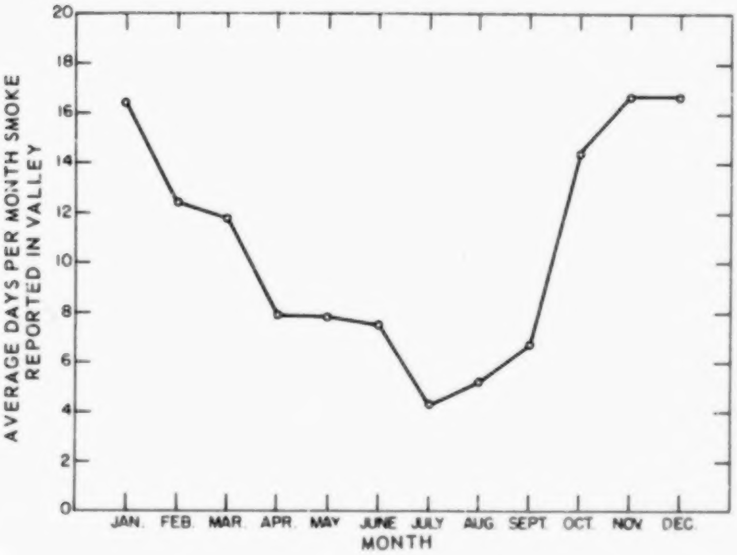


Figure 4-10. Seasonal variation of airport observations of smoke over the city, 1948–1959.

An attempt was made to evaluate the effect on visibility caused by locating the pulp mill there in 1951. Data from the Lewiston Airport smoke reports (Figure 4-11) show that before 1951, i.e., 1948 through 1950, smoke was reported an average of 5.6 days a month. Since 1951 (1952 to 1959 inclusive) smoke has been reported on average of 12.5 days a month, an increase of about 2-1/4 times.

The Study Period

Because of the extremely short distances to the landmarks, the data collected from visibility observations at the Lewiston Post Office are not conclusive. Normally, distances of 20 to 25 miles are necessary for satisfactory visibility evaluations by visual methods. Since the maximum range possible in the study was 1 mile, a completely valid study of visibility was not attainable. One significant fact did, however, emerge: on 17 of the 119 days during which observations were made, the amount of pollution was great enough to reduce visibility to less than 1 mile. Figure 4-12 illustrates the typical view in each direction on a clear day and on a day with reduced visibility. Notice that although visibility is markedly reduced to the north, east, and west, observation to the south shows little reduction. From January 1, 1962, to April 30, 1962, the Airport Weather Station reported smoke over the valley 71 of 120 days. Most of these reports were in the morning hours, from 0400 to 1200 hours as shown in Table 4-4.

The high incidence of plumes reported in the morning hours is reasonable because this is normally a time of high relative humidity. As shown in Table 4-5, the humidity was generally higher when smoke

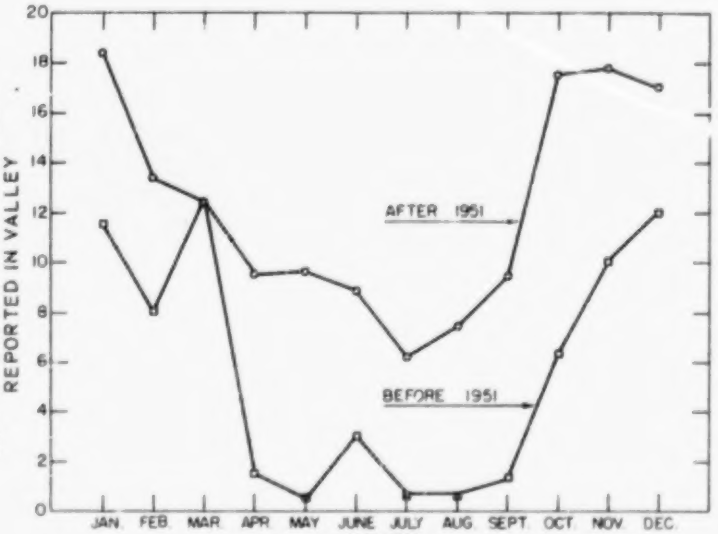
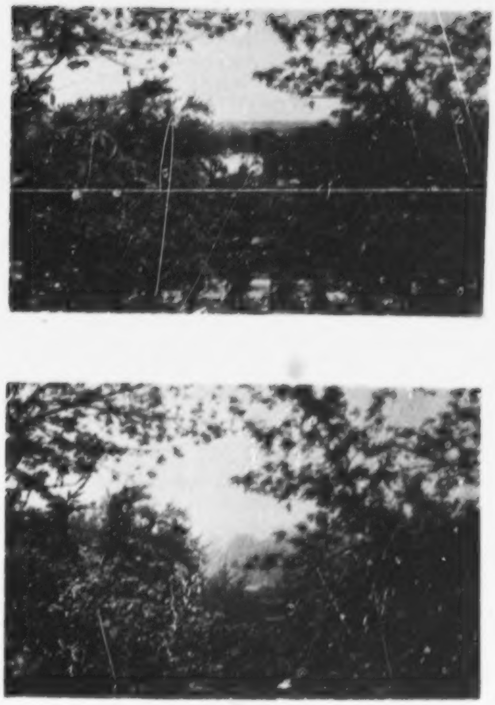
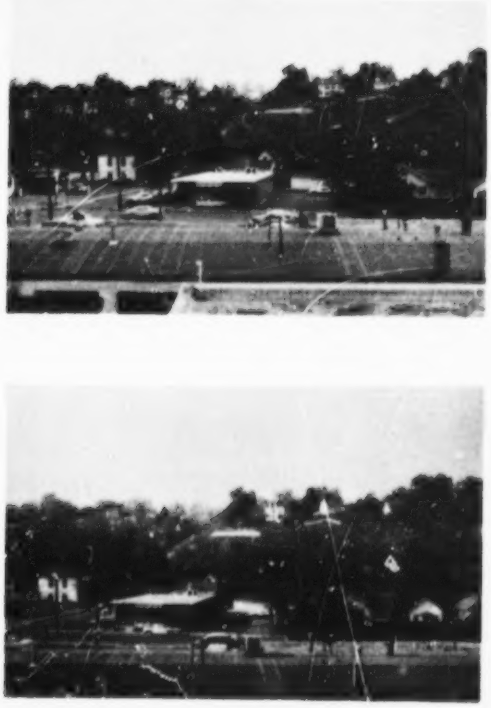


Figure 4-11. Comparison of seasonal variation of airport observations of smoke over the city, 1948–1950 versus 1952–1959.

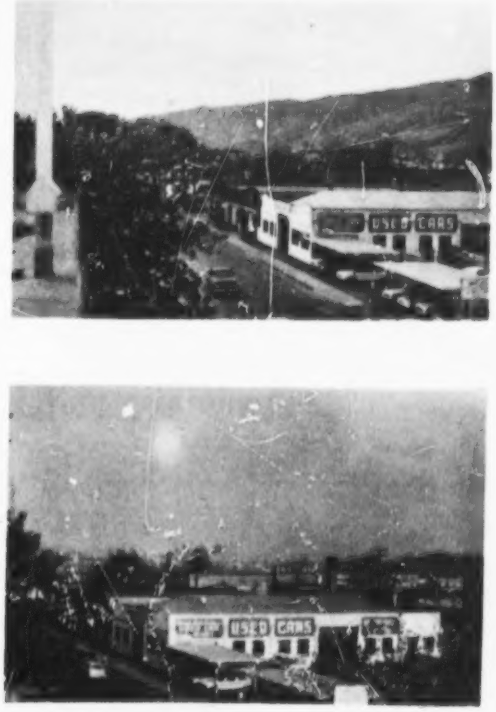
NORTH



EAST



SOUTH


USED CARS
USED CARS

WEST

Figure 4-12. Visibility observations from Lewiston Post Office building.

was reported. A comparison of average relative humidities before and after the establishment of the pulp and paper mill (Table 4-6) shows that at the city station the humidity was significantly higher during the study period than during the period of 1924 to 1933.

Table 4-4. MORNING AND AFTERNOON AIRPORT OBSERVATIONS OF SMOKE OVER THE CITY, NOVEMBER 1961 THROUGH APRIL 1962

Month	Frequency of smoke over city, %	
	0400-1200 hours	1300-2000 hours
November	62	38
December	68	32
January	63	37
February	57	43
March	81	18
April	89	11

Table 4-5. RELATIONSHIP OF 0800 RELATIVE HUMIDITY AND AIRPORT OBSERVATION OF SMOKE OVER THE CITY, JANUARY 1962 THROUGH APRIL 1962

Month	Observation	Average relative humidity, %	
		Airport	City
January	Smoke over city	75	84
	No smoke over city	62	69
	Average for month	66	74
February	Smoke over city	88	92
	No smoke over city	73	85
	Average for month	77	87
March	Smoke over city	80	94
	No smoke over city	80	91
	Average for month	80	92
April	Smoke over city	72	81
	No smoke over city	60	69
	Average for month	64	74

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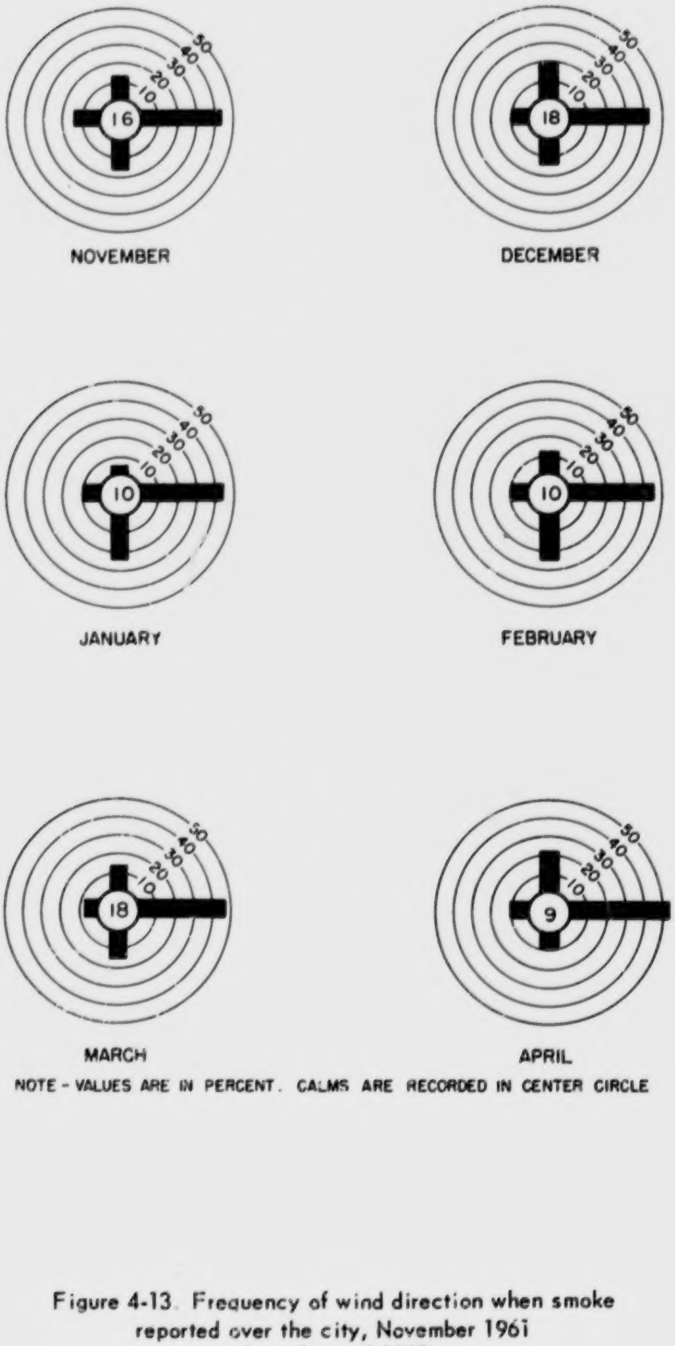
Table 4-6. COMPARISON OF CITY AND AIRPORT RELATIVE HUMIDITIES FOR STUDY PERIOD AND FOR 1924 TO 1933

Month	Relative humidity, %		
	City		Airport
	Study period	1924-1933	Study period
November	-	83	76
December	-	79	79
January	74	79	70
February	92	79	77
March	99	77	82
April	94	74	71

The moisture emitted from the pulp and paper mill has had a significant effect on the relative humidity in the valley, and it is evident that the increased humidity and particulates have adversely affected visibility in the valley.

A study of the relationship between wind direction and incidence of smoke in the valley is also revealing. During the hours when smoke was reported in the valley, the wind was most frequently out of the easterly quadrant, i.e., northeast to southeast. Figure 4-13 shows the frequencies for the 6 months of the study period. As can be seen, more than 40 percent of the smoke observations occurred when winds were from the east.

Photographs of the effects of the pulp mill on visibility in the valley are even more revealing. Figure 4-14 was made on December 25, 1961, at 0945. It views the valley from the south and illustrates the situation when the pulp mill was not in operation. Figure 4-15 was made on November 30, 1961, at 0900 and shows that an inversion over the valley prevents the dispersion of the effluent from the pulp mill. Figures 4-16 through 4-19 show the effect of the pulp mill under various conditions of stability and wind direction. Figure 4-16 is particularly interesting since it illustrates the usual wind current in the valley. Even though the wind is from the east at the mill, almost every portion of the valley beneath the inversion is affected. Figure 4-20 shows examples of uncontrolled sources of smoke in Clarkston.



NOVEMBER DECEMBER

JANUARY FEBRUARY

MARCH APRIL

NOTE - VALUES ARE IN PERCENT. CALMS ARE RECORDED IN CENTER CIRCLE

Figure 4-13. Frequency of wind direction when smoke reported over the city, November 1961 through April 1962.

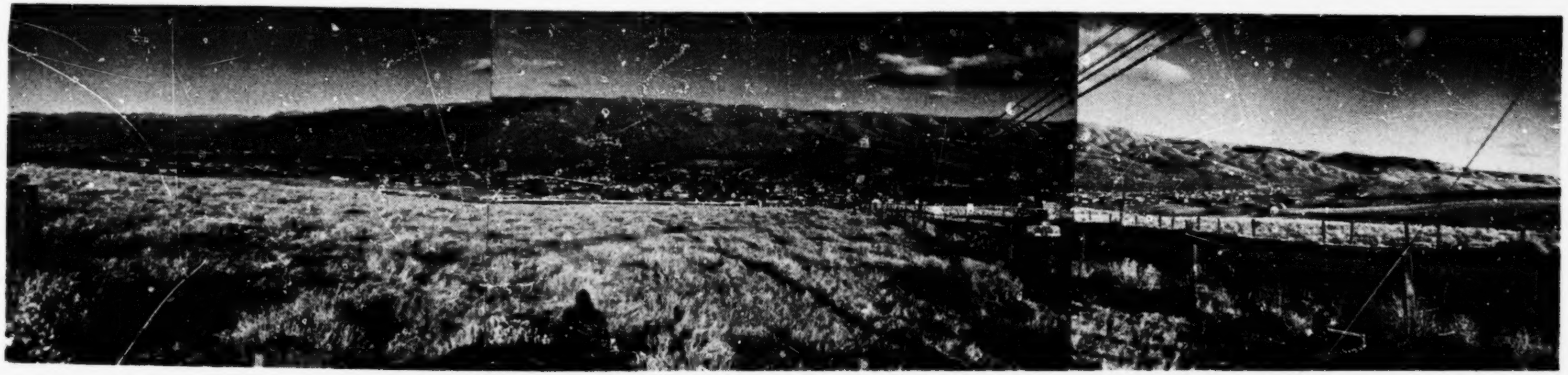


Figure 4-14. Lewiston–Clarkston valley, Dec. 25, 1961, at 0945.

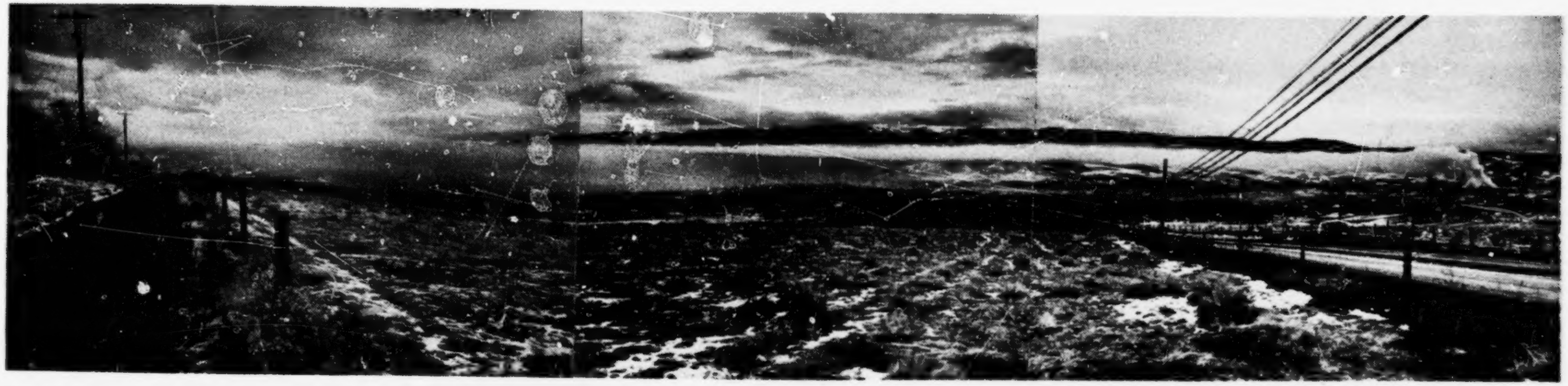


Figure 4-15. Lewiston–Clarkston valley, Nov. 30, 1961, at 0900.

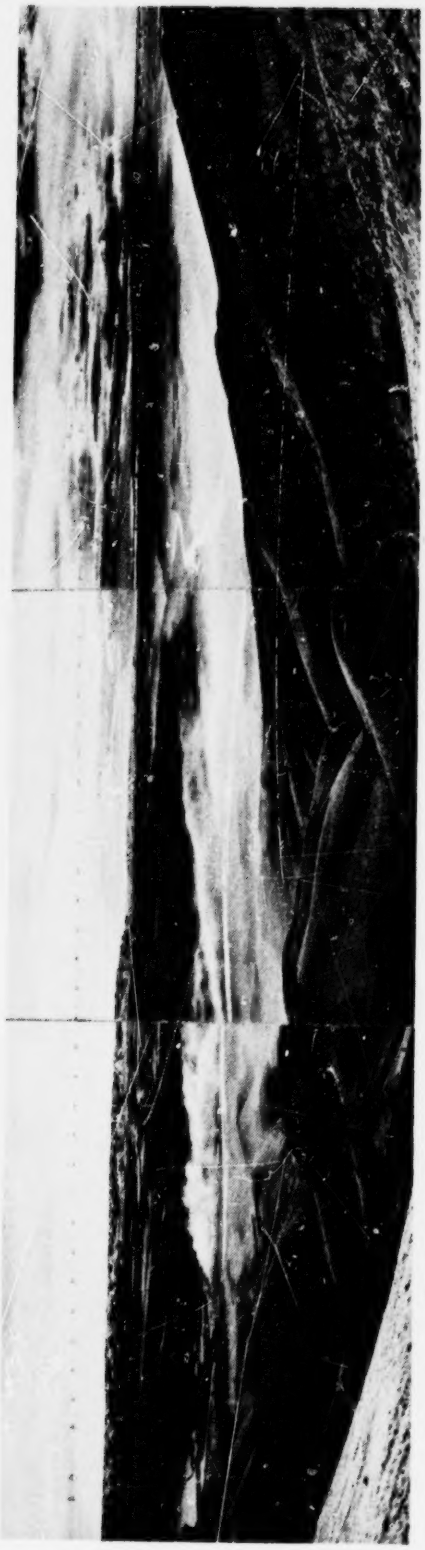


Figure 4-16. Panorama of valley looking south from north of Lewiston, Feb. 3, 1962, at 0900.

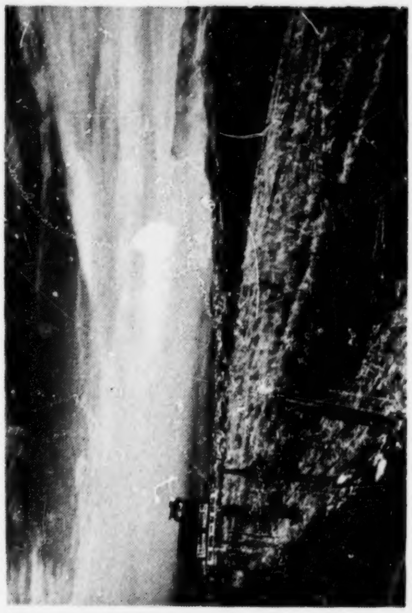


Figure 4-17. Lewiston during calm, Feb. 3, 1962, at 0900.

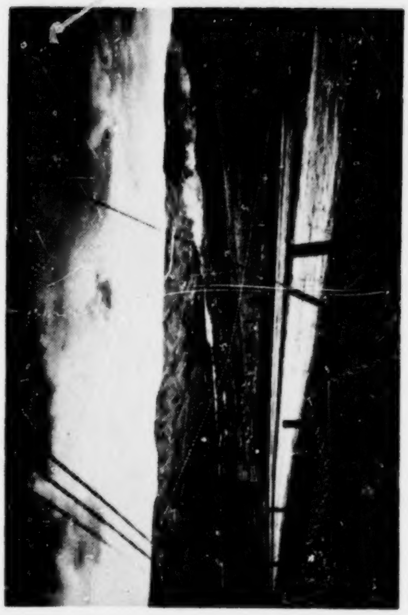


Figure 4-18. Pulp mill effluent during west wind, Dec. 3, 1961, at 0830.

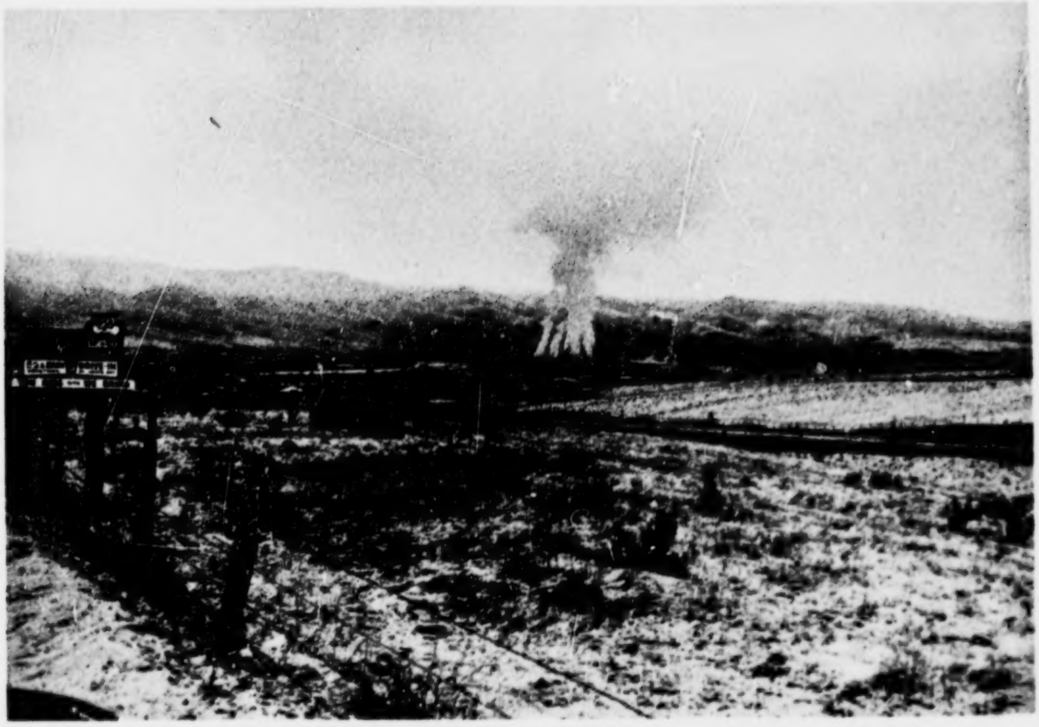


Figure 4-19. Pulp mill effluent during unstable conditions and calm wind, Jan. 16, 1962, at 0830.

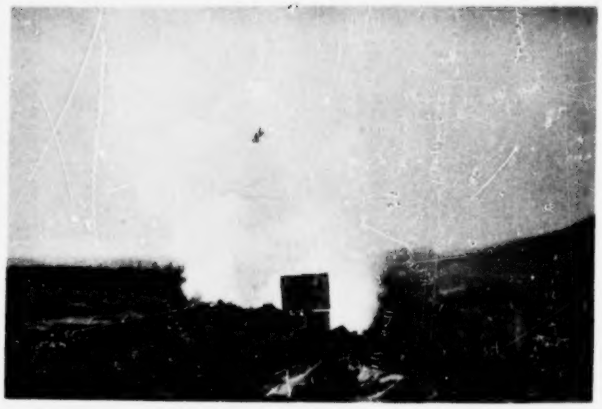
CONCLUSIONS REGARDING VISIBILITY

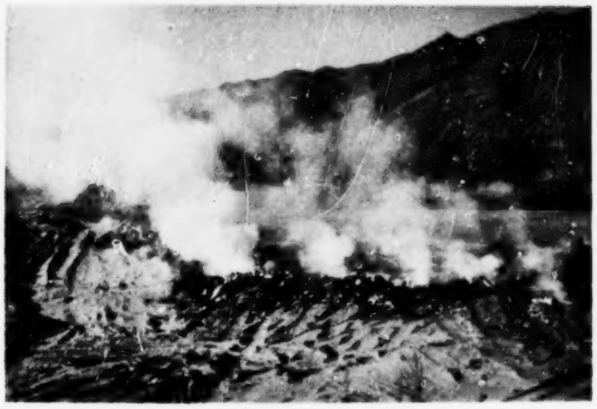
A rather severe visibility reduction problem exists in the Lewiston-Clarkston valley. Basically, the data from this study as well as meteorological data for periods of time prior to the study were correlated with the incidence of smoke in the valley. The greatest occurrence of smoke resulted from a stable, ambient atmosphere with high relative humidity and an easterly wind. The topography itself helps create a stable atmosphere with frequent inversions. As a result of economic activity in the valley, relative humidity seems to have increased to the point that particulates induce fogs more easily. Fogs combined with the smoke emissions from all sources have caused many incidents of significantly reduced visibility in the valley.

HYDROGEN SULFIDE

NATURE OF THE GAS

Hydrogen sulfide (H_2S) is a colorless gas that has, even in very small concentrations, an offensive odor described as that of rotten eggs. It occurs naturally when sulfur-containing organic matter decomposes without complete oxidation. It results also from man-made processes





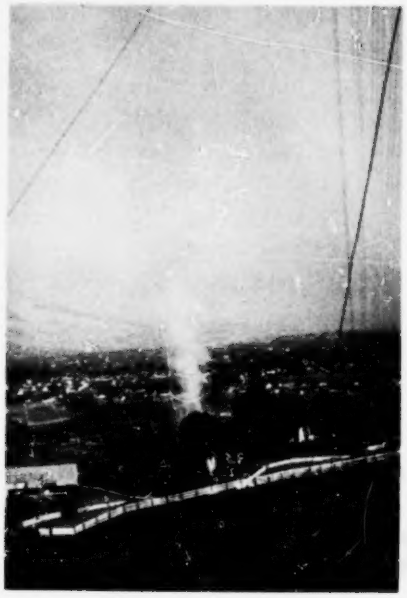


Figure 4-20. Major sources of air pollution in Clarkston, a garbage dump, a brush dump, and a saw mill waste burner.

such as the manufacture of petroleum products, paper, and many chemical compounds. As shown by the emission inventory (Chapter 3), the primary source of H_2S and other odorous gases in the Lewis-Clarkston area is the kraft pulp mill.

The minimum concentration of H_2S that is detectable is debatable. A review of the literature reveals nearly a thousandfold variation in the reported odor threshold values for this gas. Wright, a recognized authority on kraft pulp mill odors, states that one part of H_2S per billion parts of air is the minimum perceptible concentration.[1] Smith, Jenkings, and Cunningworth have suggested that 20 parts per billion (ppb) is detectable as an offensive odor,[2] whereas Moncrieff[3] suggested 100 ppb. Other scientists found that 7 to 36 parts of H_2S per billion parts of air gave slight odors in households, where constant concentrations are hard to obtain; in controlled laboratory tests, however, the lower limit was 72 ppb.[4] Dalla Valle proposed 790 ppb as the concentration causing faint odor.[5] Others have proposed 25 and 130 ppb.[6,7]

These authors have used the words "perception of faint odor." At the "perception threshold" concentrations, one is just certain that an odor exists, but it is too faint for identification. The "recognizable threshold" is the smallest concentration at which a skilled observer can identify and describe the odor or at least compare its quality with another odor.

Although the range of reported values may at first appear to be wide, one must remember that, according to the Weber-Fechner Law, the perception by smell of a change in apparent odor intensity requires a change in actual concentration by a factor of approximately 10, varying somewhat with the odor type. Thus, the sensation increases as the logarithm of the concentration of the stimulus. As reported by Stern,[7] the empirical dilution factor for H_2S is 5.9 and that for methyl mercaptan is 14.

Hence, the minimum detectable odor for H_2S probably ranges from about 10 or 15 to near 100 ppb. An ultrasensitive person might detect 1 ppb whereas a nonsensitive person may be unable to detect concentrations less than 500 ppb.

H_2S tarnishes silver and copper rapidly in concentrations of 500 ppb and slowly in concentrations as small as 3 ppb.[8] Paint blackening occurs when lead base paint, moistened with water, is exposed to the gas.

Regarding standards for protecting human health, only two have been established. The Russians have established a limiting value of 5.15 parts of H_2S per billion at one time (20-minute period) or in a 24-hour period as their standard for community air quality.[7] The State of California has established a concentration of 100 ppb for 1 hour as the "adverse level" based on sensory irritation.[9]

H_2S is not commonly used as a measure of air quality. Since concentrations arising from natural sources are generally small, H_2S is not usually measured, unless it is suspected that concentrations are large enough to constitute a problem. Since a major source of H_2S gas existed in the study area, it was necessary to measure it.

All air samples for H_2S collected in this study were 2-hour samples. When H_2S is sampled over a specific time period, for example 2 hours, the concentration measured is actually an average of many instantaneous or short-term values, large and small. If the sampling time is short, the concentration measured should be very close to the peak instantaneous value that occurred. The resulting peak-to-mean ratio would be a small number not much greater than unity. As the sampling time is increased, the probability that the average value recorded will be close to the highest instantaneous mean is reduced and the peak-to-mean ratio is larger. Attempts have been made to estimate the short-term peak concentrations from measurements based on a long sampling period.[10, 11,12] One author reports the greatest 3-minute concentration of gas to be 3.4 times the mean concentration over 1 hour for stable atmospheric conditions and 8 times the mean for an unstable atmosphere.[12] This means that the greatest 3-minute concentration of a gas probably was 3.4 to 8 times larger than that actually recorded for a 2-hour sampling period, depending on the stability of the atmosphere. The same reasoning has been applied to estimating 1-hour peak values from 2-hour samples. These ratios range from 1.3 for stable to 1.5 for unstable conditions.

AREA CONCENTRATIONS

H2S samples were collected at six stations with treated-filter tape samplers.[13] H_2S varied significantly among the stations in the valley and those in Lewiston Orchards and Moscow. A frequency distribution of H_2S concentrations by area for the 6-month study period shows that the Lewiston commercial station and both stations in Clarkston had the highest frequency of H_2S pollution. Lewiston commercial was highest; it was closest to the major source of H_2S (Table 4-7). It is expected that whenever there are measurable concentrations of H_2S at any of the stations, the elevated plume from the primary source is moving or has just previously been moving toward the west along the major axis of the valley. The frequency of large concentrations decreases with greater distance of the stations from the river (farther from the centerline of the plume). For stations at about the same distance from the river, the average frequency of large concentrations is less at the stations farther from the major source (West Clarkston compared to Lewiston commercial).

Although the Lewiston commercial station had the highest average frequency of large concentrations, both the West Clarkston and Clarkston commercial stations had high frequencies of concentrations 3 ppb or greater. As is shown later, this was due to inversion breakup and fumigation at an earlier time in Clarkston. By the time fumigation occurs in Lewiston (1200 to 1400 hours), wind speeds have generally increased, diluting the plume, and reversal of windflow to upvalley flow frequently keeps concentrations small (less than 3 ppb) at Lewiston at this time. Peak values of 10 ppb or greater were recorded most frequently at the Lewiston commercial station and the two stations in Clarkston, each being close to the centerline of the plume from the major source of hydrogen sulfide.

Percentages for the Moscow control station indicate the relatively low H_2S values recorded in the nonindustrial community.

Table 4-7. FREQUENCY DISTRIBUTION OF HYDROGEN SULFIDE CONCENTRATIONS, BY AREA, FOR STUDY PERIOD

Hydrogen sulfide concentration, ppb	Frequency at sampling station, %					
	Moscow	Lewiston Orchards	Lewiston residential	Lewiston commercial	West Clarkston	Clarkston commercial
0-2	96.0	92.2	89.1	68.1	80.5	78.6
3-9	4.0	7.3	8.6	28.2	16.9	18.9
$\geq$10	0	0.5	2.3	3.7	2.6	2.5

SEASONAL VARIATIONS

General

Each season has its own characteristic effect on the ability of the atmosphere to accept and dispose of pollutant emissions and also, therefore, on the outward manifestation of air pollution.

During summer, conditions are favorable for inversion breakup and fumigations: light air flow, stable nights, and unstable days (which tend to occur with clear skies). Because of rapid heating during summer, inversion breakup is rapid, producing large H_2S concentrations for periods of about 1/2 to 1 hour. Average concentrations are, however, smallest during the summer because of the shorter periods of darkness when conditions are stable and the generally good diffusion conditions during the day.

Fall produces somewhat fewer fumigations than summer. But inversion breakup takes longer, large H_2S concentrations are produced during fumigations lasting from 1 to 2 hours. Average concentrations are greatest in the fall since light winds and greater frequency of stagnating anticyclones produce poor over-all diffusion conditions.

During winter the frequency of east winds is high, and winds, though not as light on the average as during the fall, are frequently light throughout the day. The frequency of stagnating anticyclones is high. Inversion breakup fumigations do not occur as frequently as in either summer or fall. High, short-term (about 2- to 3-hour) concentrations can be expected to occur frequently with near neutral atmospheric conditions. Average H_2S concentrations are only slightly smaller than during the fall.

In the spring, light winds are less frequent than in summer or fall. Inversion breakup fumigations can be expected to be more frequent than during winter but less frequent than during summer or fall. Neutral conditions may be expected to produce large H_2S concentrations with somewhat less frequency than in winter. Average concentrations are greater than in summer but less than in fall or winter.

The Study Period

Since the period under study had higher wind speeds than normal and higher frequencies of westerly winds than would be expected, it was expected that frequencies of large H_2S concentrations would be generally lower than those normally occurring during this time of year.

The H_2S concentrations were related very closely to the dispersion and dilution of the pollutants by air movement in the valley. It was generally true that smallest concentrations at all stations were observed in the spring when gusty winds and a high degree of vertical mixing of the air occurred. These conditions provided better ventilation for the valley, and thus lowered pollution levels. Greatest concentrations were observed in November and February, when the duration and the frequency of inversions were most pronounced and produced conditions conducive to pollution accumulation (Table 4-8). Again, the highest pollution levels were noted at the valley stations directly in line with the major pollution source and at the lower elevations, which were most susceptible to frequent morning fumigations.

VARIATION BY DAY OF WEEK

With data from stations in the valley, variations of H_2S concentrations by day of week were studied. Friday had significantly larger average concentrations than the other days (Table 4-9). It also had a significantly higher frequency of concentrations 3 ppb or greater. Since it is not likely that freak occurrences of weather conditions conductive to pollution buildup exist on Fridays, it is concluded that the emissions of H_2S are greater on Fridays.

DIURNAL VARIATIONS

H_2S concentrations showed no variation by time of day for Moscow (Table 4-10); only background amounts were measured. Significant daily peaks of pollution occurred at the two Clarkston stations from about 0800 to 1000 and in the Lewiston commercial area from 1000 to

Table 4-8. MONTHLY VARIATION OF HYDROGEN SULFIDE CONCENTRATIONS IN PARTS PER BILLION, BY AREA, FOR STUDY PERIOD

Month	Sampling station					
	Moscow	Lewiston Orchards	Lewiston residential	Lewiston commercial	West Clarkston	Clarkston commercial
November	0.98	1.91	2.86	4.75	2.44	2.85[a]
December	0.54	1.67	1.84	1.79	2.24	1.90
January	1.21	1.43	0.84	1.29	1.58	1.72
February	0.98	1.01	2.01	2.47	2.66	2.41
March	1.02	0.73	0.92	1.62	1.76	1.77
April	0.06	0.46	0.84	1.34	1.13	1.26
Average	0.80	1.21	1.55	2.21	1.97	1.81

[a] Note: November H_2S concentration for Clarkston commercial is monthly average for controlled temperature AISI Sampler at Clarkston Fire Station.

1200. This morning peak of pollution was associated almost daily with the breakup of inversions (Figure 4-21). With inversion breakup, fumigation of the residential areas in the valley occurs (Table 4-10). The apparent delay between peaks at the Lewiston and Clarkston stations is due to two factors: (1) The north slope of the river valley is steepest just north of Clarkston; and (2) the ground near Clarkston slopes downward to the northeast, whereas the ground near Lewiston slopes downward to the northwest. Both factors allow more rapid heating by the morning sun over Clarkston, since solar heating is quicker where a surface is more perpendicular to the sun's rays. Figure 4-22, graphing the frequency of inversion breakup during the study period as determined by the Post Office station and airport hydrothermograph records, shows the same pattern as do the peaks of daily H_2S concentrations.

Table 4-9. VARIATION OF HYDROGEN SULFIDE CONCENTRATIONS BY DAY OF WEEK IN THE VALLEY [a]

Day of week	Average concentration, ppb	Number of samples ≥ 3 ppb [b]
Sunday	2.1	147
Monday	1.9	141
Tuesday	1.7	144
Wednesday	1.6	137
Thursday	1.9	174
Friday	2.4	202
Saturday	1.5	136

[a] Stations 4, 5, and 6 were used.

[b] Data from November 1 through April 25 were used, providing 25 days of data for each day of the week.

RELATIONSHIP OF HYDROGEN SULFIDE CONCENTRATIONS TO WEATHER PARAMETERS

Wind Speed

The frequencies of high and low wind speeds at the Post Office station during periods with H_2S concentrations of 3 ppb or greater were observed to determine whether wind speed had any relation to large concentrations of H_2S. In addition, the frequency of high and low wind speeds was determined without regard to H_2S concentration. The frequencies were then compared as ratios (Table 4-11). These ratios indicate that, generally, large H_2S concentrations occurred as frequently

Table 4-10. VARIATION OF HYDROGEN SULFIDE CONCENTRATIONS BY HOUR OF THE DAY AND BY AREA, FOR STUDY PERIOD

Time of sample	Hydrogen sulfide concentration, ppb					
	Moscow	Lewiston Orchards	Lewiston residential	Lewiston commercial	West Clarkston	Clarkston commercial
0000-0200	0.8	1.1	1.1	1.6	1.6	1.4
0200-0400	0.8	1.2	1.0	1.5	1.7	1.3
0400-0600	0.8	1.4	1.3	1.6	1.8	1.6
0600-0800	0.8	1.3	1.2	1.9	2.3	2.1
0800-1000	0.8	1.2	1.7	3.3	3.2	3.2
1000-1200	0.8	1.4	2.5	4.4	2.7	2.4
1200-1400	0.8	1.4	2.7	3.3	2.3	2.2
1400-1600	0.8	1.2	1.9	1.9	1.8	1.7
1600-1800	0.8	1.2	1.6	1.7	1.6	1.5
1800-2000	0.8	1.1	1.4	1.5	1.4	1.4
2000-2200	0.8	1.0	1.3	1.7	1.5	1.5
2200-2400	0.8	1.2	1.2	1.6	2.0	1.3

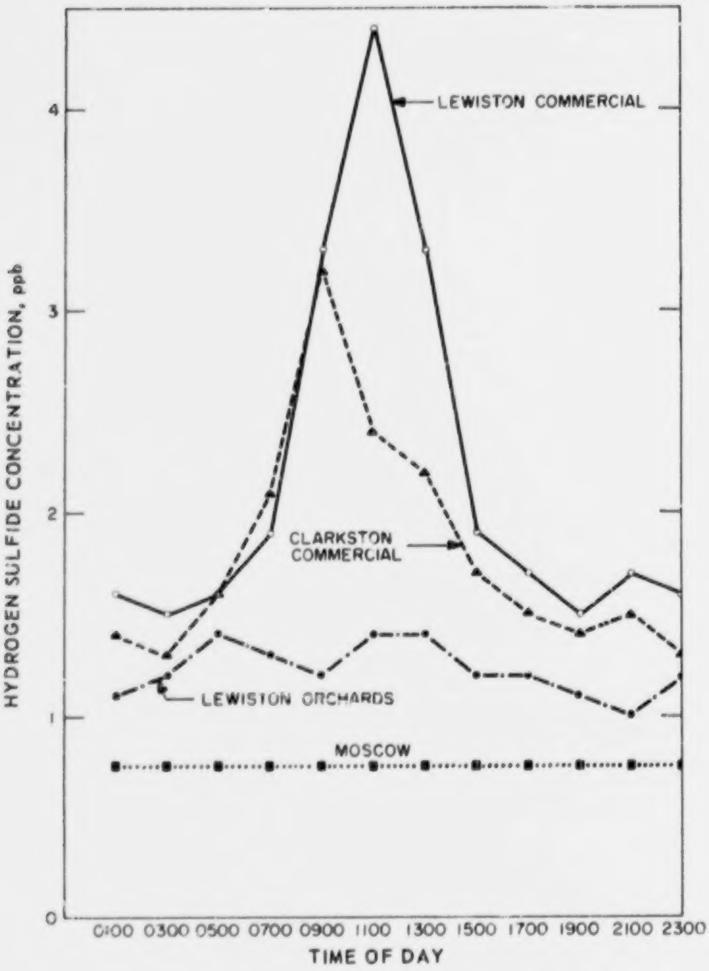


Figure 4-21. Hourly hydrogen sulfide concentrations for selected areas during the study period.

with winds greater than 3.4 mph as with lesser wind speeds. An exception was the Lewiston residential station, which had half again as many light winds with large H_2S concentrations as was expected from the frequency of occurrence for the study period. Since lesser wind speeds tend to allow higher effective stack heights and the plume from the major source remains aloft, large H_2S concentrations at ground level would not be expected to be associated with light winds. Fumigation conditions, when the lower portion of the atmosphere becomes unstable and reaches the plume aloft mixing it between the ground and its previous level, generally have surface wind speeds between 3 to 7 mph. Fumigation seems to be the principal mechanism for producing large concentrations at ground level.

Table 4-11. COMPUTED RATIO OF OBSERVED TO NORMALLY EXPECTED FREQUENCIES OF HYDROGEN SULFIDE POLLUTION WITH WIND SPEEDS,[a] BY AREA, FOR STUDY PERIOD

Sampling station	Ratios (R)[b]	
	Wind speed ≤ 3.4 mph	Wind speed > 3.4 mph
Lewiston Orchards	0.9	1.2
Lewiston residential	1.6	0.7
Lewiston commercial	1.2	0.9
West Clarkston	1.1	1.0
Clarkston commercial	1.1	0.9

[a] Post Office weather station.

[b] $R = \frac{W_I}{W_T} \times \frac{P_t}{P_i}$

W_I = Number of observations of wind speed in a given category (i.e., above or below 3.5 mph) over the study period.

W_T = Total observations of wind speed in all (both) categories over the study period.

P_i = Number of observations of wind speed in a given category when hydrogen sulfide pollution was measured at 3 ppb or greater.

P_t = Total of all observations of wind speed in all (both) categories when hydrogen sulfide pollution was measured at 3 ppb or greater.

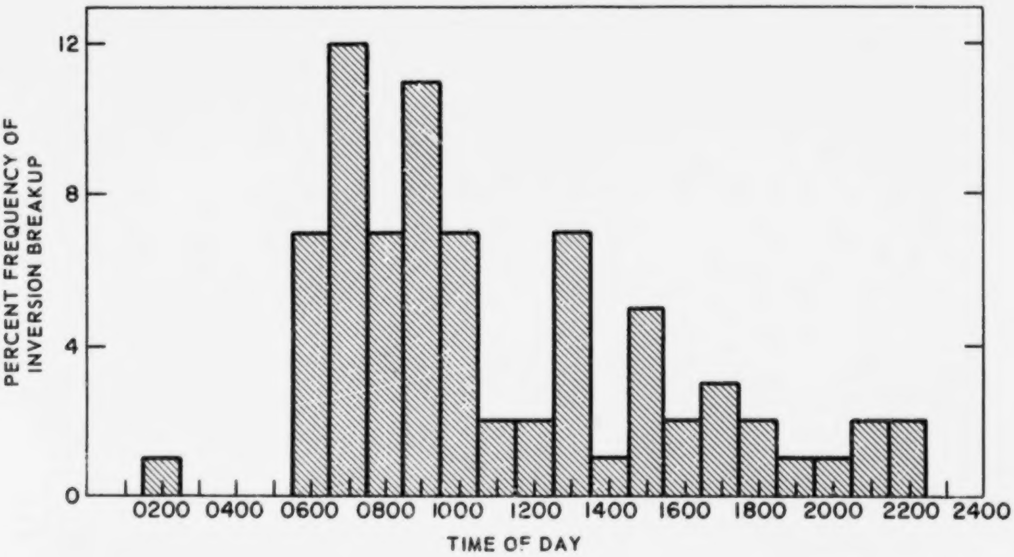


Figure 4-22. Estimated percent frequency of inversion breakup by hour of day for study period.

Wind Direction

Ratios of frequencies of wind direction were also calculated from the Post Office wind direction records. These are shown in Table 4-12. Ratios in the northwest quadrant are generally high, probably because (1) the Post Office winds generally shift to upvalley and up the south slope prior to fumigations and (2) the Post Office station frequently shows a northwest wind when the flow is from the southeast at the airport, which is presumably a result of the standing eddy in the lee of the abrupt rise just south of the post office.

Episodes During Study Period

A study of the frequency of high levels of pollution greater than 10 ppb by area substantiates the findings of Table 4-7. The most severe pollution was observed in November at most stations and was most pronounced at the valley stations (Table 4-8). The Lewiston commercial station showed 11 days in which H_2S concentrations of 10 ppb or greater were observed. During these 11 days, 24 samples, covering a period of 48 hours, exceeded 10 ppb. The forecasting program of the U.S. Public Health Service indicated a 48-hour stagnation period would occur from November 7 to 9, 1961. H_2S concentrations were relatively low on the 7th, increased somewhat on the 8th, and reached peaks on the 9th. On the 10th, concentrations had diminished approximately to those of the 7th. The maximum daily concentration, 14.4 ppb, was recorded at the Lewiston residential station. The maximum 2-hour concentration, 51 ppb, occurred at this station November 9. Conditions conducive to a second episode existed in late January and for the first 2 days of February 1962. Although not as great as in November, H_2S concentrations

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Table 4-12. COMPUTED RATIO OF OBSERVED TO NORMALLY EXPECTED FREQUENCIES OF HYDROGEN SULFIDE WITH WIND DIRECTION, BY AREA, FOR STUDY PERIOD

Wind direction	Ratio (R)[a]			
	Lewiston residential station	Lewiston commercial station	West Clarkston station	Clarkston commercial station
N	0.42	1.12	0.92	1.36
NNE	0.72	1.44	0.83	1.26
NE	0.24	0.79	0.35	0.96
ENE	0.31	0.39	1.28	1.02
E	2.38	0.31	3.15	1.03
ESE	0	0.36	0	0.27
SE	0	0.58	0	0.43
SSE	1.00	2.00	0.31	0.25
S	1.79	1.19	0	0
SSW	2.08	0.69	0.33	0.52
SW	0.47	0.99	0.30	0.24
WSW	1.10	0.28	0.26	0.21
W	2.29	0.51	0.48	0.76
WNW	5.56	0.31	2.04	2.09
NW	3.25	2.17	1.36	2.16
NNW	0.37	1.73	2.21	2.50

[a] $R = \frac{D_I}{D_T} \times \frac{P_t}{P_i}$ Where:

D_I = Number of observations of wind direction in a given category (i.e., north, north-northeast, northeast, etc.) over the study period.

D_T = Number of total obervations of wind direction in all categories over the study period.

P_i = Observations of wind direction in a given category when H_2S pollution was measured at ppb or greater.

P_t = Total observations of wind direction in all categories when H_2S pollution was measured at 3 ppb or greater.

of 24 to 26 ppb for 4 hours were observed at the three valley stations. These maxima occurred on February 1, 1962.

Weather Associated With High Hydrogen Sulfide Concentrations

All 2-hour periods during January through April 1962 with H_2S concentrations of 10 ppb or greater at any of five stations (81 periods) were studied to determine the meteorological conditions associated with them. (There were no concentrations 10 ppb or greater at station 2.) During none of these periods were concentrations 10 ppb or greater at more than three stations. During 60 periods, concentrations were ≥ 10 ppb at only one station; during 16, at two; and during 5 at three (Table 4-13).

Forty-eight periods were associated with inversion breakup fumigations causing relatively large concentrations as the elevated stable plume was mixed uniformly between the ground and its original height. During the vertical mixing, the plume width increased but was still small enough so that relatively large concentrations occurred between 0400 and 1600

Table 4-13. OCCURRENCE OF HYDROGEN SULFIDE CONCENTRATIONS 10 ppb OR GREATER

	Station No.										
Time	3 Alone	4 Alone	5 Alone	6 Alone	3,4	3,5	4,5	4,6	5,6	3,4,6	4,5,6
0000-0200			1	1							1
0200-0400			3								
0400-0600				1					1		
0600-0800		1	2	2					1		
0800-1000	1	1	4	2		1	1	1	4		
1000-1200	1	3	4	2	1			2			1
1200-1400	1	5	4	2	1		1	1		1	
1400-1600	1	1	1	1	1						
1600-1800	1			2							
1800-2000	1	1	1	3							
2000-2200	2		2								1
2200-2400	1			1							1
Totals	9	12	22	17	3	1	2	4	6	1	4
	60				16					5	

and only beneath and near the centerline of the plume. Two of these periods affected three stations, 15 affected two, and 31 affected only one. Since stations 4, 5, and 6 were affected more frequently, it is likely that the plume flowed from east to west along the rivers. There were, however, 10 periods with a northeasterly component, and from the observed concentrations, it appeared likely that the plume moved south up the Snake River valley rather than west down it. The largest concentrations that occurred during fumigation conditions were 28 ppb at station 3, 60 ppb at station 4, 43 ppb at station 6, and 44 ppb at station 6.

Neutral conditions were considered to have affected concentrations during 22 periods; only one was affected during 18 periods, two during 1, and three during 3. These occurred between midmorning and late afternoon. Probably somewhat stronger winds in the valley caused the plume rise to be much lower than the 200 meters noted in photographs. It is possible that the periods during evening hours were fumigations due to the instability and mixing caused by the city. Of particular interest were eight consecutive 2-hour periods (1800 on February 1 to 1000 on February 2, 1962). During three of these periods, concentrations were ≥ 10 ppb at stations 4, 5, and 6. The highest concentrations observed were: Station 4, 26 ppb; 5, 26 ppb; and 6, 33 ppb.

Winds at the airport were calm at 1800; between 0400 and 1000 were from the south and south-southeast at 8 to 16 mph. Winds were not observed at the airport from 1900 to 0400, but were estimated to be from the south through southeast at 7 to 16 mph, and probably produced a general east-to-west flow in the valley causing the plume from the major source to move downvalley. Winds at the Post Office during this entire period were from the north and north-northwest at 2 to 9 mph. This was probably the result of an eddy that formed to the lee (in this case north) of the rather abrupt rise just to the south of the Post Office (Figure 4-23) and that helped lower the elevated plume moving downvalley, which increased ground level concentrations of H_2S.

Slightly unstable conditions were believed to cause three periods of high concentrations (10, 17, and 25 ppb) between 1000 and 1600 at Station 4 only.

On eight occasions Station 3 was the only one with 10-ppb or greater concentrations, principally during the afternoon and evening hours. This probably resulted from the elevated plume encountering the south slope of the valley but remaining aloft or diffusing before reaching the other station. Concentrations ranged from 10 to 26 ppb.

Although 10-ppb or greater concentrations frequently lasted only during a 2-hour period at a given station, on numerous occasions concentrations remained great for up to five consecutive 2-hour periods. Table 4-14 shows the frequency of persistence of 10-ppb or greater H_2S concentrations at four stations. Table 4-15 gives the frequency of different concentrations at 10 ppb or greater.

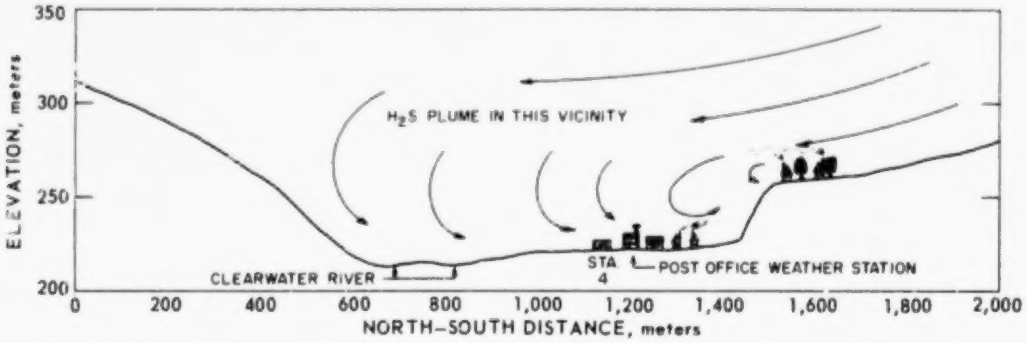
350
300
250
200
ELEVATION, meters
H₂S PLUME IN THIS VICINITY
CLEARWATER RIVER
STA
4
POST OFFICE WEATHER STATION
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
NORTH–SOUTH DISTANCE, meters

Figure 4-23. Expected wind structure in the vicinity of the post office during February 1-2, 1962 (VERTICAL SCALE EXAGGERATED 4 TIMES).

Table 4-14. FREQUENCY OF PERSISTENT PERIODS OF HYDROGEN SULFIDE CONCENTRATIONS 10 ppb OR GREATER[a]

Duration, hr	Station			
	3	4	5	6
2	8	9	18	13
4	1	1	6	6
6		5		1
8	1			1
10			1	

[a] Two-hour average.

Estimation of H_2S Concentrations During Periods of High Pollution Potential

From photographs of the plume, it is estimated that with light winds (1 to 2 meters per second) the effective height of the major source was 200 meters, presumably because of the buoyancy of the effluent. An estimate of fumigation concentration of H_2S beneath the centerline of the plume was made by the formula from Gifford [14]

$$x_f = \frac{Q}{\sqrt{2\pi}\,\sigma_y \mu H}$$

Table 4-15. FREQUENCY OF OCCURRENCE OF HYDROGEN SULFIDE CONCENTRATIONS 10 ppb OR GREATER [a]

H_2S concentration, ppb	Station			
	3	4	5	6
10-19	9	15	21	18
20-29	5	7	11	9
30-39		3	1	4
40-49			2	1
60-69		1		

[a] Two-hour average.

where x_f is the concentration in grams per cubic meter, Q is the source strength in grams per second, σ_y is the horizontal standard deviation of concentration in meters, μ is the mean wind speed in meters per second, and H is the height in meters to which the elimination of the inversion has extended. Estimates of H_2S emission for the principal source were made in Chapter III. Diffusion estimates were taken from Gifford; [15] the following assumptions were made: The plume has been moved from the source by an average wind speed of 1 meter per second, the plume is mixed uniformly in the vertical to a height of 250 meters above the river, the plume prior to fumigation has been influenced by moderately stable diffusion conditions, and the horizontal standard deviation of plume concentration increases threefold during the fumigation process. The resulting concentrations at Stations 4, 5, and 6, if each Station is beneath the plume centerline, are as follows: Station 4, 65 ppb, dropping to 10 ppb at a distance of 550 meters from the plume centerline; Station 5, 30 ppb, dropping to 10 ppb at 900 meters; and Station 6, 40 ppb, dropping to 10 ppb at 800 meters. No computations were attempted for Station 3 because it is about 50 meters above the river and the model used cannot easily allow for the elevation difference. The calculated fumigation concentration would be smaller for wind speeds greater than 1 meter per second and larger for mixing heights below 250 meters. The greatest concentrations observed for 2-hour periods during fumigation conditions have previously been given as: Station 3, 28 ppb; 4, 60 ppb; 5, 43 ppb; and 6, 44 ppb. These were also the greatest concentrations observed under any conditions during January through April.

By means of the Gaussian plume model, [14] at neutral dispersion conditions, wind speed of 2.5 meters per second, and effective height of emission of 100 meters, the concentration, if each station is beneath the centerline, is calculated as: Station 4, 47 ppb, lessening to 10 ppb at a distance of 320 meters acrosswind from the plume centerline; Station 5, 25 ppb, lessening to 10 ppb at 550 meters; and Station 6, 37 ppb, lessening to 10 ppb at 520 meters. The greatest observed 2-hour concentrations during neutral conditions were; Station 4, 26 ppb; 5, 26 ppb; and 6,33 ppb. This is in close arrangement with the above computations.

By means of the Gaussian plume model, and on the assumption of dispersion conditions, wind speed of 2.5 meters per second, and effective height of 100 meters, the concentration, if each station is beneath the centerline, is calculated as: Station 4, 29 ppb, lessening to 10 ppb at a distance of 390 meters from the plume; Station 5, 7 ppb; Station 6, 12 ppb, lessening to 10 ppb at 280 meters. The greatest concentration observed during unstable conditions when one station had concentrations 10 ppb or greater were: Station 4, 25 ppb; Station 5, 3 ppb; and Station 6, 9 ppb.

Comparative Studies of Atmospheric Hydrogen Sulfide Concentrations

A well-established and often-used wet chemical test, the methylene blue procedure (see Appendix), substantiated the validity of H_2S concentrations obtained by the treated-filter tape samplers. For three 2-week periods, one each in November, January, and April, continuous 2-hour air samples were collected and analyzed at the Clarkston Fire Station by the two methods; thus 42 days of sampling with 12 daily samples produced about 500 methylene blue samples for comparison.

Although the principal point of interest was the correlation of results between the methylene blue procedure and the "standard" treated-filter tape samplers, two additional samplers were operated for comparison. For one, the air was passed through a long, spiralled, glass tube submerged in a constant-temperature water bath to produce an air temperature of approximately $70^{\circ}F$ at the sampler. The second sampler differed from the "standard" samplers in the type of vacuum pump employed; it used a diaphragm pump, which produces a somewhat variable flow rate at the filter tape.

November was the only period during which a significant number of air concentrations (36) greater than 2 ppb were recorded, amounting to 20 percent of the November samples. January showed two and April four (Table 4-16). Because of a shortage of instruments, the standard filter tape sampler was not operated in November at the control station.

When the readings of the standard sampler, the controlled-temperature sampler, and the diaphragm pump sampler were compared with the results of the methylene blue test, the standard and controlled-temperature tape samplers were within ±1 ppb of the methylene blue results 85 and 84 percent of the time (Table 4-17). The diaphragm pump tape sampler was within ±1 ppb on 63 percent of the samples.

Table 4-16. FREQUENCY DISTRIBUTION OF H_2S CONCENTRATIONS OBTAINED BY THE METHYLENE BLUE PROCEDURE

Concentration, ppb	Occurrences		
	November	January	April
0	23	123	113
1	101	26	41
2	16	2	8
3	11	1	2
4	7	1	0
5	4	0	2
6	5	0	0
7	2	0	0
8	3	0	0
9	2	0	0
≥10	4	0	0
	178	153	166

TAPE FADING

H_2S was determined from the treated-filter tapes by use of a photometer (see Appendix). The light transmittance through the reacted darkened tape was recorded and interpreted from a calibration curve in terms of H_2S in parts per billion. The field practice of removing the tapes from the machine after about 2 weeks of operation for reading on the photometer raised questions concerning the possibility of a darkened spot fading with time. As a general rule, tapes were removed from the machines and accumulated until a sufficient number was collected to warrant sustained use of the photometer. As a result, some tapes were read several weeks after collection. If fading of the spots (i.e., lightening of the lead sulfide spot collected) had occurred, light transmittance would have been higher and the measured H_2S concentrations lower than the true value.

A brief laboratory check of tape fading was conducted on two separate tapes collected in late March and early April. A total of 336 samples on the tapes were reread. A time lapse of from 65 to 88 days had occurred at the time of the final reading. Initial readings had been made from 7 to 26 days after collection. Initial readings of the samples checked showed 298 to be above 90 percent transmittance and only 38 samples below 89 percent transmittance (Table 4-18). Of the 336 samples, 122 showed identical transmittance readings, 116 showed

Table 4-17. COMPARISON OF TREATED-FILTER TAPE SAMPLER RESULTS WITH METHYLENE BLUE PROCEDURE RESULTS

Tape sampler compared	Month	Number of methylene blue samples compared	Deviation of results from methylene blue procedure, % of samples	
			0 ppb	Within ±1 ppb
Standard treated-filter tape sampler	November	---	--	--
	January	153	41	90
	April	166	61	77
		319 (total)	49 (avg)	85 (avg)
Controlled-temperature tape sampler	November	178	27	75
	January	153	50	95
	April	166	61	85
		497 (total)	45 (avg)	84 (avg)
Diaphragm pump tape sampler	November	178	20	59
	January	153	7	36
	April	166	66	91
		497 (total)	32 (avg)	63 (avg)

increased transmittance (spot faded), and 98 showed decreased transmittance (spot darker). Although only a few samples in the low transmittancd range were evaluated, no apparent difference was noted in the average amount of increase or decrease between these and the lightly spotted samples (i.e., 90 to 100% transmittance).

It is concluded that fading of the collected lead sulfide is not a problem when the exposed tapes are sealed in a relatively airtight container, which was the handling procedure employed throughout the study.

To evaluate the influence of changing line voltage on readings obtained with the photometer, several tapes were read with and without

Table 4-18. COMPARISON OF INITIAL AND FINAL LIGHT TRANSMITTANCE READINGS FOR EVALUATING TAPE FADING

Initial light transmittance, %	Difference in light transmission					
	No difference	Increase (faded)		Decrease (darkened)		Total
	No. of samples	No. of samples	Average increase, %	No. of samples	Average decrease, %	
90-100	117	96	3	85	3	298
80-89	1	14	6	2	4	17
70-79	2	5	4	2	3	9
60-69	0	0	0	4	3	4
50-59	0	0	0	3	3	3
≤ 50	2	1	5	2	2	5
Total	122	116		98		336

a constant-voltage regulator in the line ahead of the photometer. Although occasional fluctuations in line voltage were noted, similar readings were obtained with both procedures.

CONCLUSIONS REGARDING H_2S

Atmospheric hydrogen sulfide (H_2S) concentrations were determined at four sampling sites in Lewiston, two in Clarkston, and one in Moscow (control site) with impregnated filter paper sequential samplers. Samples were collected over 2-hour periods for a 6-month period (November-April). Atmospheric H_2S concentrations varied directly with the distance from the pulp mill. Greatest concentrations generally occurred between 0800 and 1200, coinciding with the time of inversion breakups, which result in ground fumigation. Little or no diurnal variation was observed at the control station, indicating that only background H_2S concentrations were present. The maximum 2-hour concentration measured was 60 ppb, which was recorded at the Lewiston commercial sampling site. The average 2-hour concentration for 6 months at this station was 2.2 ppb, compared with 0.80 ppb at the Moscow control site.

The results obtained with treated-filter paper samples compared favorably with samples collected in a wet scrubber and analyzed by the methylene blue method. Investigation of the stability of the lead sulfide stains produced on the filter paper samples revealed little loss of sample in approximately 3 months when the exposed tapes were sealed in a relatively airtight container.

SULFUR DIOXIDE

Sulfur dioxide (SO_2) is an irritating and toxic gas with a taste threshold of 0.3 ppm and an odor threshold of 3.0 ppm.[16] The State of California selected an SO_2 concentration of 0.3 ppm for an 8-hour period as its standard for ambient air quality.[17] For periods of 1 hour, 1 ppm was selected. Sensitive varieties of certain plants show damage at 0.04 ppm for 7 hours.[18] A major source of SO_2 is the combustion of fuel (see emission inventory). The SO_2 emission from this source depends on the sulfur content of the fuel and to a lesser degree the method of firing, but the bulk of the sulfur is emitted after oxidation as SO_2. At times industrial process emissions can also be a major source of SO_2. Concentrations of this gas in ambient air also were of interest since large concentrations caused interference with the wet chemical procedure used for measuring H_2S. One investigator demonstrated that when SO_2 concentrations were approximately 100 times those of H_2S, the methylene blue procedure gave low and erratic results.[19] The concentrations used in his experiment were believed to range from 0.5 to 60 ppm.

In this study, 2-hour SO_2 samples were collected and analyzed continuously for approximately 2-week periods in November, January, and April by use of the West-Gaeke procedure (see Appendix).[20] A total of 512 samples - 191 in November, 153 in January, and 168 in April - were analyzed. During November, SO_2 values ranged from 0 to 15 ppb (0.015 ppm), with an average of 3.2 ppb; during January, from 0 to 25 ppb, with an average of 4.7 ppb; and during April, from 0 to 11 ppb, with an average of 1.1 ppb. The greater concentrations were observed during the colder periods, which indicated that fuel burning for space heating is a primary source of SO_2 in the area. Further, a check of meteorological conditions in April reveals the almost daily occurrence of gust winds. Thus, with increased ventilation to dilute the pollutants, lesser concentrations would be expected.

The greatest average concentration for any one sampling day occurred on November 20, 1961, with an average of the 12 samples measuring 9 ppb. The maximum daily average in January was 7 ppb and in April, slightly less than 3 ppb (Table 4-19). Concentrations were observed to be maximum at 0900 for both November and January (Table 4-20). This agrees with meteorological data, which showed inversion breakup occurring in the late midmorning hours. H_2S concentrations showed a similar maximum from about 0900 to 1100.

In view of the small concentrations of SO_2 observed, no problem at the present time is believed to exist, although additional sources of SO_2 or changes in the fuel pattern could conceivably produce sufficient con-

Table 4-19. AVERAGE DAILY SO_2 CONCENTRATIONS

November		January		April	
Date	Concentration, ppb	Date	Concentration, ppb	Date	Concentration, ppb
11/4	2	1/7	3	4/15	1
11/5	3	1/8	2	4/16	3
11/6	3	1/9	7	4/17	2
11/7	2	1/10	6	4/18	2
11/8	3	1/11	5	4/19	<1
11/9	4	1/12	6	4/20	<1
11/10	2	1/13	6	4/21	1
11/11	2	1/14	7	4/22	2
11/12	2	1/15	2	4/23	1
11/13	3	1/16	7	4/24	<1
11/14	2	1/17	3	4/25	<1
11/15	3	1/18	5	4/26	<1
11/16	3	1/19	5	4/27	<1
11/17	6			4/28	<1
11/18	5				
11/19	4				
11/20	9				

centrations to pose a problem under adverse weather conditions. Secondly, at the concentrations measured, no interference was likely with the methylene blue method of analysis for H_2S.

CONCLUSIONS REGARDING SO_2

Twelve 2-hour atmospheric sulfur dioxide (SO_2) samples were collected and analyzed daily during 2-week periods in November, January, and April. The greatest 24-hour concentration (9 ppb) occurred in November. The greatest 2-week average concentrations (5 ppb) occurred in January, indicating that fuel burning for space heating is a primary source of SO_2 in the area. In view of the small atmospheric concentrations present, SO_2 is not considered to be a major air pollutant in the area.

Table 4-20. VARIATION OF SULFUR DIOXIDE CONCENTRATIONS WITH TIME OF DAY

Time period	Concentration, ppb		
	November	January	April
0000-0200	3	3	1
0200-0400	2	4	1
0400-0600	3	4	2
0600-0800	3	7	2
0800-1000	6	9	1
1000-1200	3	1	<1
1200-1400	3	3	1
1400-1600	2	6	<1
1600-1800	3	2	0
1800-2000	4	6	<1
2000-2200	3	6	2

ODORS

GENERAL

Modern man lives amid diverse odors and odoriferous materials. Although the total number of outright stenches has decreased with the decline of tanning, candlemaking, and other noxious and offensive operations, man has substituted diversity for strength. This diversity may be attributed in part to industrial operations, though many other community activities may also result in odors. The response to any given odor is subject to individual variation, and it may or may not be considered objectionable.

Man's perception of odors is not as acute as that of some lower animals, though some individuals, through training or natural ability, are acutely sensitive to slight differences in odors. In any one community, however, sensitivity should be normally distributed, from exceptional to nil.[21]

The problem of precisely defining an offensive odor is difficult. An odor may be pleasant to one and offensive to another person because of psychological factors that may cause unpleasant association with the odor. An objectionable odor cannot be defined as one that is offensive to all individuals exposed to it, since there will always be a few who will be blissfully unaware of even the most fetid stench.[22]

A working definition of an offensive odor may be: an odor that is objectionable to the majority of healthy persons exposed to its olfactory action.

CRITERIA FOR ODOR SURVEYS

An accurate determination of the distribution of odors in this area cannot be readily achieved by an investigation of each complaint. Instead, a systematic odor survey is needed to: (1) provide community-wide coverage, (2) establish areas most severely affected, (3) determine when and how often people experience odors, and (4) provide results that can convince offenders that they are creating an air pollution problem.

METHODS OF ODOR SURVEYS

Techniques for evaluating community odor problems normally include: surveys by many untrained observers,[26, 27] odor evaluations by trained observers aided by mechanical diluting devices,[21,25,28,29] or chemical evaluations.[30-34] Trained observers can gather more detailed information, but usually, because they are so few, cannot achieve the wide area coverage possible with a survey technique. Untrained observers are usually unable to make detailed observations, but the total of observations is large, and the area coverage is wide.

METHODOLOGY OF THIS ODOR SURVEY

Objectives: The objectives of this survey were to determine:

1. The major odor types in the area.
2. The areas most severely affected and the type of odor involved.
3. The season, day of week, and time of day when odors are most often observed.
4. The variables that may influence observer response, e.g., human and meteorological variables.

The first three involve the practical aspects of the odor problem, whereas the fourth involves information useful both for the present study and future surveys.

Selection of Observers

One of the first problems was selection of observers. There were two possibilities: use of a few highly trained observers or use of many observers with little or no training. Both methods were used. The trained personnel were selected from the Clarkston and Lewiston city engineering departments. Two men from each city made odor observations using scentometers to help establish odor strength at various points in the community.

The untrained observers were selected from high school students in the two communities; somewhat over 100 students participated during each phase of the study. The procedure used to evaluate observers and details of the method for conducting odor sensitivity tests are outlined in Appendix A.

Factors Influencing Odor Sensitivity

One would expect a group of individuals collected at random to have degrees of sensitivity to odors that could be graphed along the familiar bell-shaped curve. If all the groups are more or less sensitive than average, however, the results reflect this. Another complicating factor is that an individual's sensitivity to odors varies from day to day. It was found, however, that day-to-day variations do not affect the results of the scentometer.[21]

Several factors are involved in an estimation of the variation of individual sensitivity:

1. The sense of smell is rapidly fatigued.
2. Fatigue for one odor does not necessarily affect the perception of dissimilar odors, but does affect the perception of similar odors.[22]
3. Responses to odors are not completely objective since phychological responses vary in different observers.
4. Some persons are extremely sensitive, whereas others are incapable of smelling an odor. Age seems to affect sensitivity, with a maximum at puberty and a decrease with age.
5. Many observers have reported[22,23] that odors become stronger in fog. The effect of temperature on odor has been noted, but is linked to the formation of fog.

Meteorological factors have an influence on the reported levels of odors,[23] with wind speed and inversion occurrence determining the dilution of odors in the air. Topography also may affect the transport of odors and may cause pockets of trapped odorous air that persists.

The problem of odor fatigue is impossible to eliminate. The community under study would be considered highly odorous by newcomers to the area. Within an hour of arrival, however, a marked reduction in odor, caused by fatigue, is noticeable. One can reverse the fatigue effect by traveling out of the valley for several hours, but the fatigue returns soon after re-entry.

It is impossible to estimate how much resensitization to odors the valley residents undergo during periods of low odor concentration or during periods when ventilation of the valley is sufficient to dilute the odorants present. No attempt was made, therefore, to measure or estimate the possible effects of fatigue on the response. It would seem that persons living in Lewiston Orchards and possible Clarkston Heights

Table 4-21. COMPARISON OF THE TOTAL POSSIBLE AND ACTUAL OBSERVATION RESPONSES BY SURVEY PERIODS AND AREAS

Survey period and area	Number of students	Possible observations [a]	Actual observations	Percent response (% = 100 x $\frac{\text{actual}}{\text{possible}}$)
November total	120	5,040	3,817	75.7
Clarkston	51	2,142	1,650	77.0
Clarkston Heights	7	294	289	98.3
Lewiston	32	1,344	943	70.2
Lewiston Orchards	30	1,260	935	74.2
April total	110	4,620	3,169	68.6
Clarkston	37	1,554	1,167	75.1
Clarkston Heights	6	252	204	81.0
Lewiston	37	1,554	1,072	69.0
Lewiston Orchards	30	1,260	726	57.6

[a] Possible observations = number of students x 14 days x 30 observations per day.

face the problem of adapting to the odors in the valley every morning as they travel to work.

To eliminate some of the psychological factors in odor response, the student observers were asked to note all odors whether pleasant or unpleasant. They were also asked to note whether the odor was strong or faint, and to describe it in their own words. Classifications of observed odors (Table 4-23) were made upon the basis of descriptions reported by the observers.

Conduct of the Surveys

Odor surveys were made from November 7 to November 20, 1961, and from April 15 to April 28, 1962. The students made three observations daily: at approximately 0700, 1600, and 2000. The trained observers had specified routes thoughout the area, with approximately 10 sampling stops. The trained observers also released small helium-filled balloons to determine the wind direction and to estimate the wind speed.

The student observers recorded their observations on cards (Appendix A). Instructors in the two high schools collected the cards each day.

The responses in both surveys are shown in Table 4-21. The poorest response was 57 percent in April, but even this figure was considered good.

The sex and grade level of the students are shown in Table 4-22. The girls were more conscientious observers in both studies, and freshmen and sophomores were more conscientious than juniors and seniors.

Table 4-22. COMPARISON OF THE AVERAGE NUMBER OF OBSERVATIONS WITH THE SEX AND GRADE LEVELS OF THE STUDENT OBSERVERS FOR EACH SURVEY PERIOD

	November		April	
	Number of observers[a]	Average observations per student	Number of observers	Average observations per student
Total number of student observers	120	32	110	29
Males	50	29	44	28
Females	70	33	66	29
Freshman and Sophomores	78	35	96	30
Juniors and Seniors	31	27	14	23

[a] The high school grade is unavailable for 11 student observers in the November survey.

Table 4-23 shows the odor classifications used. Type 0 odors, flowers, were not used in November but were used in April. The students were not told to report by odor type, to prevent any possibility of influencing the results.

Table 4-23. CLASSIFICATION OF ODORS FOR THE STUDENT ODOR SURVEY

Odor type	Observed odor as described by students
1	PFI (Potlatch Forest, Incorporated, mill), cabbage, rotten eggs
2	Smoke, wood smoke
3	Burning leaves
4	Wet grass, musty
5	Gasoline, oil, exhaust, road tar
6	Rendering plant, rotten flesh
7	Rubbish, burning trash
8	Animal odors
9	Miscellaneous odors
0	Flowers
None	No odor observed

MAJOR ODOR PROBLEMS

By Area

The frequency distribution of responses by area and study period is shown in Table 4-24. Approximately 30 percent of the total responses involved some type of odor, and about 10 percent involved Type 1 odors of either faint or strong intensity. Tables 4-25 and 4-26 show the distribution of the positive odor responses for the November and April studies respectively. Since the pulp mill odors represent the largest single nuisance odor category, analysis was confined largely to this type.

Analysis of variance procedures was used to establish the presence of significant differences in the pulp mill odor responses for each area. Since the total number of students responding on any given day varied, the proportion of positive responses to the total responses for that day was used rather than absolute numbers of positive responses. Ninety-five percent confidence levels were used throughout the analysis.*

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* See Appendix C

Table 4-24. DISTRIBUTION OF ODOR RESPONSES BY SURVEY PERIOD AND AREA

Survey period and area	Total observations	No odor	Positive odor response			Type 1		
			Total	Faint	Strong	Total	Faint	Strong
November total	3,817	2,489	1,328	900	428	442	276	166
Clarkston	1,650	888	762	502	260	238	139	99
Clarkston Heights	289	141	148	96	52	45	30	15
Lewiston	943	721	222	149	73	107	70	37
Lewiston Orchards	935	739	196	153	43	52	37	15
April total	3,169	2,476[a]	693	510	183	233	165	68
Clarkston	1,167	907	260	183	77	134	85	49
Clarkston Heights	204	157	47	31	16	5	4	1
Lewiston	1,072	845	227	176	51	63	52	11
Lewiston Orchards	726	567	159	120	39	31	24	7
Grand total	6,986	4,965	2,021	1,410	611	675	411	234

[a] "No odor" for the April survey includes responses to Type 0 (flowers) odors.

The results show a significant difference among the areas. In November, the percent response of Lewiston students to pulp mill odors was significantly greater than the average, while that of all the others was lower than average. In April, the positive responses in Clarkston were greater than average, while all others were lower than average. There was no significant difference between individual days during either of the study periods.

Odors from burning leaves (Type 3) did not vary significantly in the four areas. Similarly, the odors from burning wood (Type 2) showed no variation. The burning rubbish odor (Type 7) was, however, reported significantly more often in November in both Clarkston and Clarkston Heights, which indicated that openly burning trash dumps are a localized problem in the Clarkston area.

By Time

Since there was a definite peak of H_2S concentrations in the morning, the possibility of a greater frequency of pulp mill odor responses in the morning was investigated. For both study periods, the morning response to pulp mill odors was significantly greater than the average.

The other type odors had a somewhat different distribution by time (Table 4-27). Burning wood, burning leaves, and burning rubbish all elicited peak odor responses in the afternoon. Although these odors affect the entire region to some degree, they do not behave as the pulp mill odors. Emissions from burning wood, leaves, and rubbish are basically ground level, and are not caught in the inversion nor dropped at breakup since an inversion usually does not occur during the day.

Based on the responses to all odor types, there was no difference between the two study periods, except for a significant difference between November and April in pulp mill odor responses in the Lewiston area only.

ODOR PERCEPTION VERSUS HUMAN VARIABLES

General

Several possible human variables were studied to determine whether they affected the results.

Sex Differences

It has been reported in the literature that females are more sensitive than males to odors. A comparison of the sensitivities of the girl respondents versus the boys showed that there was no significant difference for either study. The data for this study can be used, therefore, without regard to the sex of the observer.

Table 4-26. FREQUENCY OF POSITIVE ODOR RESPONSE BY AREA AND ODOR TYPE – APRIL

Odor type	Clarkston		Clarkston Heights		Lewiston		Lewiston Orchards	
	37 students		6 students		37 students		30 students	
	Positive responses	Total positive response, %	Positive responses	Total positive response, %	Positive responses	Total positive response, %	Positive responses	Total positive response, %
1	134	51.6	5	10.6	63	27.7	31	19.5
2	28	10.8	14	29.8	39	17.2	41	25.8
3	7	2.7	0	0.0	4	1.8	10	6.3
4	2	0.8	7	14.9	12	5.3	9	5.7
5	4	1.5	0	0.0	28	12.3	4	2.5
6	6	2.3	0	0.0	1	0.4	1	0.6
7	42	16.2	5	10.6	10	4.4	4	2.5
8	5	1.9	2	4.3	5	2.2	12	7.5
9	32	12.3	14	29.8	65	28.6	47	29.6
Total	260	100.00	47	100.0	227	100.0	159	100.0

Table 4-25. FREQUENCY OF POSITIVE ODOR RESPONSE BY AREA AND ODOR TYPE – NOVEMBER

Odor type	Clarkston		Clarkston Heights		Lewiston		Lewiston Orchards	
	51 students		7 students		32 students		30 students	
	Positive responses	Total positive response, %	Positive responses	Total positive response, %	Positive responses	Total positive response, %	Positive responses	Total positive response, %
1	238	31.2	45	30.4	107	48.2	52	26.5
2	228	30.0	41	27.7	76	34.2	78	39.8
3	92	12.1	8	5.4	19	8.6	22	11.2
4	41	5.4	5	3.4	3	1.3	11	5.6
5	23	3.0	4	2.7	3	1.3	5	2.6
6	12	1.6	8	5.4	1	0.5	2	1.0
7	66	8.6	12	8.1	5	2.3	12	6.1
8	19	2.5	11	7.4	0	0.0	8	4.1
9	43	5.6	14	9.5	8	3.6	6	3.1
Total	762	100.0	148	100.0	222	100.0	196	100.0

Table 4-27. PERCENT DISTRIBUTION OF POSITIVE RESPONSES TO SELECTED ODORS PY TIME OF DAY FOR EACH SURVEY PERIOD

Observed odor type	November			April		
	0700	1000	2000	0700	1000	2000
Total positive responses [a]	35.0	32.5	32.5	33.3	33.4	33.3
1	42.0	29.0	29.0	45.5	26.6	27.9
2	20.4	46.9	32.5	18.0	35.3	46.7
3	12.8	62.4	24.8	14.3	57.1	28.6
7	25.8	43.3	30.9	23.1	52.3	24.6

[a] Odors of flowers (Type 0) were not used in this comparison.

Influence of Colds

A commonly held view is that persons with a cold cannot perceive odors as well as those without colds. To test this hypothesis, data from the sensitivity tests given in April were analyzed with regard to colds as a variable. The analysis showed that there was no significant difference in sensitivity between students who reported having colds and those who did not. This variable then had no statistical effect on the data.

Sensitivity Differences

Since H_2S can anesthetize the odor-sensing organs, residents of areas receiving high concentrations of this pollutant may temporarily lose their ability to smell. It is possible, then, that the sensitivity of the two groups as a whole would be different and would affect the response from each area. An analysis of variance procedure was used to test for significant differences in sensitivity. The results show that, as measured by the sensitivity tests, there was no difference between the odor sensitivities of students in Clarkston and those in Lewiston. Results from each area can, therefore, be compared.

Conclusions Regarding Odors

An odor survey was conducted in the Lewiston-Clarkston area during 2-week periods in November and April with an observer corps of approximately 100 high school students. Odor observations were made at three specified times daily.

The data showed that pulp mill odors represent the largest single nuisance category. The percentage of positive pulp mill odor responses was highest in Lewiston during November and highest in Clarkston in April. The number of reports of burning leaves or wood did not vary significantly between areas. Odors attributed to open trash burning were reported more frequently in the Clarkston area in November, indicating a localized problem. Pulp mill odors were reported more frequently in the morning. Odors from the burning of wood, leaves, and rubbish were reported more frequently in the afternoon.

SUMMARY

The evaluation of air quality included measurement of ambient concentrations of suspended particulate matter, hydrogen sulfide, and sulfur dioxide at five sampling stations in the Lewiston-Clarkston area, and at a control station in Moscow, Idaho. Visual and photographic observations were used to measure visibility reduction. Odor surveys were conducted in the two communities in November and April.

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CHAPTER V. SOME EFFECTS OF AIR POLLUTION

DETERIORATION OF MATERIALS

People are accustomed to the changes in their surroundings caused by wind, rain, and other natural forces, but deterioration of man-made products caused by these forces and by atmospheric pollution is not obvious. Gaseous, liquid, and particulate byproducts of man's industry are vented to the atmosphere and poured down the sewer. Byproducts of combustion from home heating and automobile operation pass into the atmosphere to add to the "witches brew" there.

An estimate of the national economic damage resulting from air pollution is about 7.5 billion dollars annually. [1] Included are injuries to vegetation and livestock, corrosion and soiling of materials and structures, depression of property value, etc. With such a large economic loss nationally from air pollution, each community should be interested in assessing local damage.

A study undertaken here included an attempt to evaluate the effect of local air pollution on two materials: white lead-base house paint and silver plate.

The white lead-base paint is sensitive to hydrogen sulfide (H_2S) under certain conditions, and some communities have reported whole houses blackened from H_2S episodes. The silver plate approximates silverware. As any housewife knows, during some seasons, constant polishing is needed to keep silverware bright, whereas at other times silverware tarnishes very slowly. Silver plate is sensitive to compounds of sulfur including H_2S and is a much more sensitive indicator of these compounds than is lead-base paint.

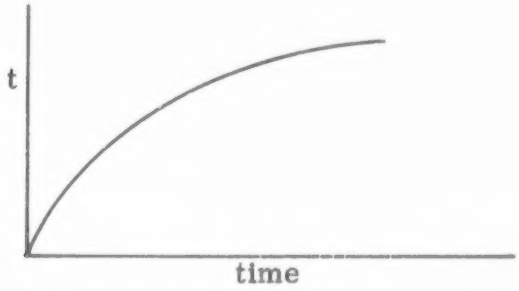
SILVER TARNISHING

The clean surface of metal is rapidly oxidized when exposed to air. The initial reaction is rapid, but oxidation decreases as a protective film of oxide is formed. At first, this film, at ordinary temperatures, is normally invisible. Prolonged oxidation or an increase in temperature may result in films that produce interference colors. High temperatures and prolonged oxidation produces thick surface layers of oxide or scale. [2]

If substances other than oxygen are present, the surface film may be composed of a mixture of oxides and other reaction products. Normally, there is some sulfur in industrial atmospheres, which results in metal tarnish films composed of oxides plus sulfides. Silver forms sulfide and sulfate in preference to oxide if any sulfur compound, either organic or inorganic, is present. [2] The sulfide film of silver, unlike the oxide, forms a visible tarnish even at room temperatures. [3]

The rate of reaction of metals with gases to form corrosion coatings depends on the relative permeability of the coating to the reactants. A porous corrosion film is less protective than a nonporous film that adheres tightly to the metal surface.[4] An example of the latter is the oxide film that forms on aluminum and prevents further oxidation. The formation of tarnish on silver seems to be an electrochemical phenomenon[2] in which metal ions diffuse through the surface film to react with the sulfur compounds. There is some movement of reactant ions toward the metal surface, but the metal ions diffuse much faster. The silver sulfide film formed on the surface of the silver does not halt further reaction, as does the oxide film of aluminum, but lowers the rate of reaction.

As a result of the electrochemical nature of silver tarnishing, the formation of the surface film follows the parabolic-growth law.[5] According to this description, the silver sulfide film forms rapidly when the silver surface is clean and untarnished. As the reaction proceeds, a layer of tarnish is formed, and the reaction rate decreases in a semiexponential function. The following graph shows the general form of the curve where t represents film thickness.[3]



The film continues to form for a long time, but at a decreasing rate.

Various methods of detecting and measuring films on metal surfaces are reported in the literature; these include galvanometric, electrical, and optical.[2] The method of measurement used in this study was based on light reflectance. In essence, the method consists of measuring the decrease of reflectance of a silver plate as the tarnish film builds up. The instrument used consisted of a galvanometer and a light unit that directed a beam of light on the silver blank at an angle of 60 degrees to the normal. The specular beam was registered by a photocell and the resulting current measured by the galvanometer unit. Initial measurements were made on all unexposed silver plates and periodic measurements were made thereafter during the exposure period.

On the basis of decrease in reflectance, a comparison was made of different exposure sites throughout the area. Silver plates were exposed at the Moscow, Idaho, "control" station to provide information on tarnishing in a nonindustrial community. It is believed that the results of the tarnishing measurements are a fair indication of relative pollution by sulfur compounds. The results are not quantitative, but comparisons can be made between one station and another with reference to the "control" station.

Procedure

Silver blanks were made from 3- by 3- by 1/8-inch brass plates coated with copper and then with silver by electrodeposition. The silver, 1/2 mill thick, was buffed to remove tarnish and oil films, and then the plates were wrapped in sulfide-free paper to prevent formation of tarnish before exposure. The instrument used for the reflectance measurements was a Photovolt-Photoelectric Reflection Meter Model 610. A reference of known reflectivity was used to standardize the instrument.

Reflectance readings were made on all samples prior to placement. On each blank, reflectance readings were taken at six areas; the results were averaged.

It was found necessary to place new samples in the field every month because of the reduction in reactivity with thickening tarnish film, as predicted by the parabolic-reaction equation. The "old" samples were left exposed for the remainder of the study. Thus, the first sample at each station would remain at the field for 6 months, whereas the second would remain only 5 months, etc. Reflectance readings were made on all samples at each station at least once every 2 weeks. (Table 5-1.)

Results

In evaluation and interpretation of the results of the silver-tarnishing measurements, several previously mentioned factors must be considered. The silver surface becomes less reactive as the tarnish film builds up and becomes almost unreactive after a time. Normally the samples suffered a rapid decrease in reflectivity for the first 30 days and a lesser decrease the next 90 days. Thereafter, reflectivity did not change significantly, as is shown by Figure 5-1, which presents the results obtained from the first samples and indicates the decrease in reflectivity with time.

Reproducibility of results is another important consideration. [2] Great care must be observed in preparing and exposing samples and in measuring reflectivity, and even then, absolute reproducibility is not obtainable. Factors that affect the reproducibility of the results may be divided into two categories, namely, those that involve the environment and those that involve the metal surface. The metal surface is affected by dirt, surface films, oil films, stresses introduced by polishing, [3] and a variety of other factors. The surface film may appear as a smear or even a "thumbograph" [3] when the metal surface is not completely clean. From photographs, it can be observed that a smearing of the tarnish film did occur (Figure 5-2).

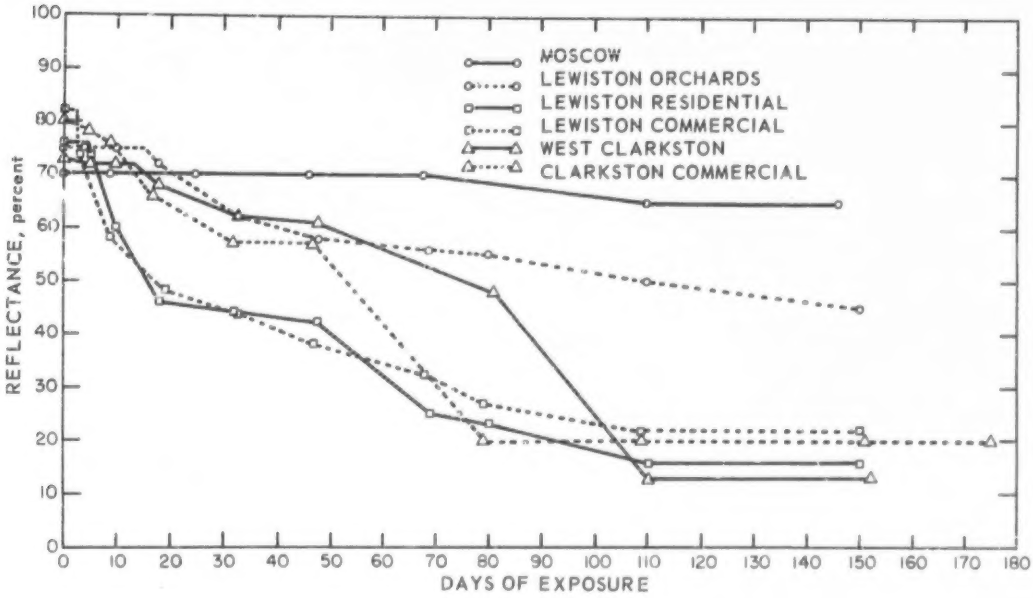


Figure 5-1. Rate of tarnishing of silver samples for 6-month study period.

One other factor contributing to the observed smearing effect is the variation in reactivity across the silver surface itself. When a metal surface is machined or abraded, stresses are induced in the metal both from mechanical action and from the heating that results. [2] Since the silver samples were buffed with a polishing compound, some residual surface stress might be expected to remain in the metal. Annealing under an inert atmosphere would remove the surface stresses, but this was not done. The effect of the uneven stress distribution in the surface of the sample promotes reaction on the lines of stress, whereas reaction on the unstressed portions of the sample occurs at the normal rate. The faster reaction at lines of stress, together with the effect of surface films of oil or oxide mentioned previously, results in the mottled appearance of some of the samples.

Smearing or mottling of the surface film hinders an accurate measurement of the tarnishing rate. The areas that are relatively untarnished remain highly reflective whereas the heavily tarnished areas are much less reflective. The net effect is to introduce into the readings a variability that reduces the reproducibility of the results. The smearing does not obviate drawing of conclusions from the tests, but some variability in the results must be allowed for.

The environmental factors that affect the reproducibility of results are humidity, temperature, and homogeneity of the atmosphere. The effect of humidity on the tarnishing of silver is not particularly significant. [2,5] Some atmospheric water must be present for tarnishing to

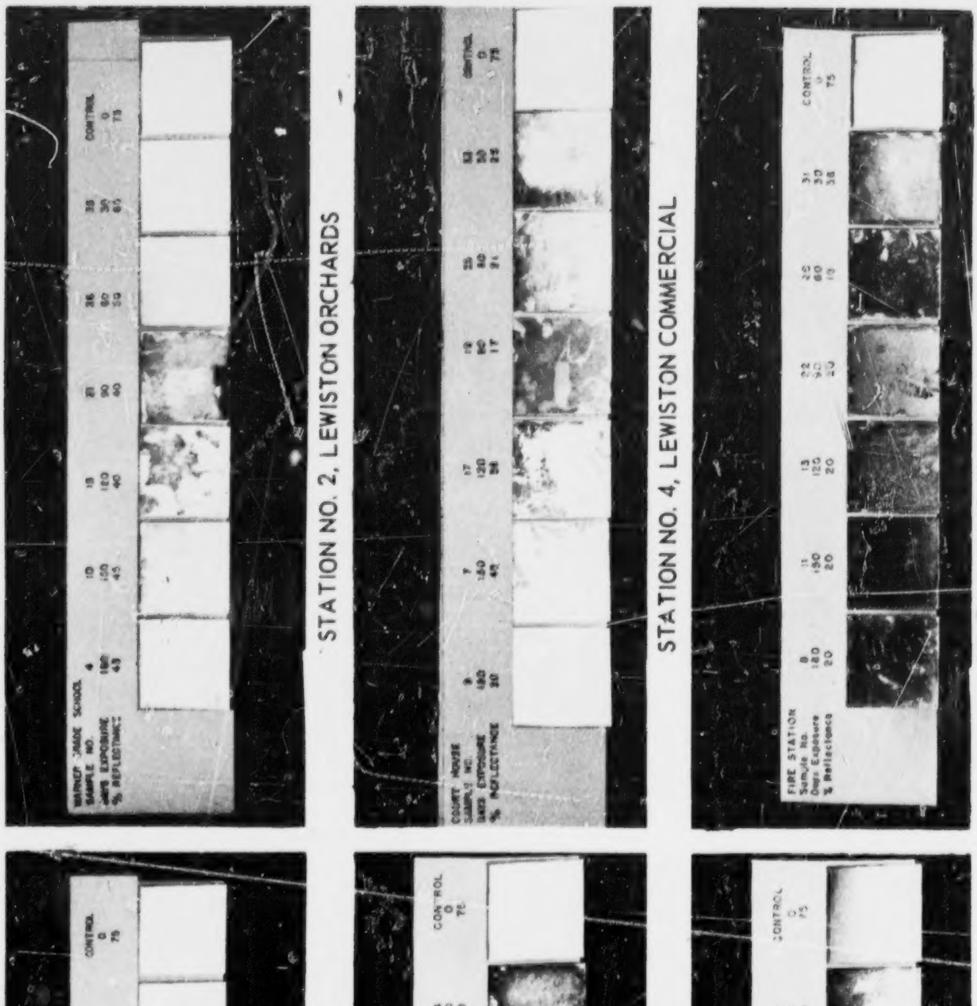
Table 5-1. RATE OF SILVER TARNISHING BY AREA DURING STUDY PERIOD

Date of reading	Cumulative decrease in reflectance, %																																				
	1 Moscow						2 Lewiston Orchards						3 Lewiston residential							4 Lewiston commercial							5 West Clarkston					6 Clarkston commercial					
Sample number	1	2	18	24	30	36	4	10	15	21	26	35	3	6	16	20	27	34	37	9	7	17	19	25	33	38	5	14	23	29	32	8	11	13	22	28	31
November																																					
3							75						76														73					80					
4																				82																	
7	70[a]	70																																			
8							0						2							8							1					2					
13							0						15							24							1					4					
16	0	0																																			
							3						28							34							5					14					
21																																					
29	0	0																																			
December																																					
6							13	76					32	76						32	78						11					23	78				
20																																					
21							18	9					34	25						44	6						12					23					
22																																	31				
January																																					
10			71						72						63							70						71						69			
11	0	0					19	17					51	44						50	13																
22							20	18	2				53	45	7					55	21						25					60	60				
23																												5						14			

Table 5-1. RATE OF SILVER TARNISHING BY AREA DURING STUDY PERIOD (Continued)

Date of reading	Cumulative decrease in reflectance, %																																				
	1 Moscow						2 Lewiston Orchards						3 Lewiston residential							4 Lewiston commercial							5 West Clarkston					6 Clarkston commercial					
Sample number	1	2	18	24	30	36	4	10	15	21	26	35	3	6	16	20	27	34	37	9	7	17	19	25	33	38	5	14	23	29	32	8	11	13	22	28	31
February																																					
1										78						80							81						77						76		
22				83																																	
19													60	55	45	48																					
21							25	20	16	14										60	30	20	65				60	60	61			60	60	50	55		
22	5	0	0	0																																	
March																																					
1					75																																
30	5	0	0	1	0						74						79							78						73						75	
April																																					
1												79						70							78						81						75
2							30	30	30	33	13		60	55	45	65	40		75	60	30	35	65	60		67											
4																											60	60	65	9		60	60	50	55	22	
15	5	0	0	5	0	80	30		30	40	17	10		55				30	26	60	30	30	65	60		45											
16															45	65	60								55		60	60	65	16	22	60	60	50	55	49	17
28	5	0	0	20	10	20								55	45	65	60	40	45	60	30	35	65	60	55	45	60					60	60	50	55	55	40
29																												60	65	25	35						
Final reflectance, %	65	70	70	65	65	60	45	45	40	40	50	65	15	25	20	15	20	30	30	20	50	35	15	20	25	20	10	10	10	50	50	20	20	20	20	20	35

[a] Underlined number shows reflectance reading for each sample before exposure.



STATION NO. 1, MOSCOW

STATION NO. 2, LEWISTON ORCHARDS

STATION NO. 3, LEWISTON RESIDENTIAL

STATION NO. 4, LEWISTON COMMERCIAL

STATION NO. 5, WEST CLARKSTON

STATION NO. 6, CLARKSTON COMMERCIAL

Figure 5-2. Photographs of tarnished silver samples.

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occur, but normal conditions supply more than enough. Silver is unlike many other metals in that there is no critical humidity below which its tarnishing ceases. [2,6] The ambient temperature over the ranges encountered in this study would have little detectable effect on the tarnishing rate. [2]

Consideration of the effect of rapidly changing atmospheric concentrations of sulfides on the silver samples cannot be neglected. After exposure to several "slugs" of tarnish-producing gases, a sample may be so tarnished that it is somewhat desensitized to smaller concentrations of gas. In some particularly bad periods during the study, samples suffered a 50 percent decrease in reflectivity after less than 2 weeks of exposure. Ideally the samples should be constantly monitored and replaced when their reflectivity falls below an optimum level. In this study, equipment was not available for continuous monitoring. The readings represent an average decrease over the time between the readings rather than the day-to-day variation.

Figure 5-1 presents the changes of reflectance as a function of exposure time for the six original samples, which remained in the field for the duration of the study, a total of 150 days each for five samples and 175 days for one.

The slope of a curve indicates the tarnishing rate over any particular time period. As expected, the samples tarnish rapidly the first month and then become slightly resistant to further tarnishing. Several exceptions to the expected behavior may be observed. The Moscow sample showed almost no tarnishing over the study period, suffering a gradual decrease of reflectivity of no more than 5 percent. This small decrease is attributable to dust and variation in the measurement technique. Since this nonindustrial community was our "control" station, no tarnishing was expected and almost none was found. Both original samples in Clarkston and one in Lewiston show a rapid decrease in reflectivity for 30 days with a break in the curve, a leveling off, and then after 2 weeks another decrease of reflectivity. The exact cause of the leveling off of the tarnishing curve and the subsequent increase in tarnishing rate is not known. Two factors are important, the surface effects on the metal sample and the changes of atmospheric concentration of sulfide gases. As the tarnish film thickens, the metal surface becomes less reactive to small concentrations of sulfide gases. H_2S measurements for the first few weeks of December show relatively little pollution. This fact, plus the decreased reactivity of the metal surface, seems to account for breaks observed in the tarnishing curves.

The final level of tarnishing reached by each sample indicates the sulfide pollution in the area. The curves group themselves into three levels: Moscow, Lewiston Orchards, and the Lewiston-Clarkston area. This is what would be expected, since Moscow has little sulfide pollution, whereas Lewiston Orchards is high enough above the valley to escape most of the pollution.

Tarnishing in each area is shown by month in Figure 5-3. The data were taken from the first 30 days of exposure of each of the samples, which were exposed at roughly 30-day intervals. During the first few weeks of exposure, the samples were very reactive, and so it is believed that the first 30 days represents a more accurate measurement of pollution.

The lowest average tarnishing, for all stations except Moscow, was noted in January and December. H_2S measurements show relatively little pollution in December and January, which agrees with the silver-tarnishing measurements.

Conclusions Regarding Silver Tarnishing

Several important conclusions may be drawn from Figures 5-1 through 5-3. First, the tarnishing rate of silver plate is greater in the Lewiston-Clarkston area than in Moscow and Lewiston Orchards. As shown in Figure 5-4, the decrease in reflectivity in the Lewiston commercial area is the greatest (an average of 41% for the 6 months); the decrease is least for Moscow (4%). During individual months, the difference in tarnishing rate was sometimes larger, with a maximum difference in February when reflectivity of the Lewiston commercial sample decreased by 68 percent. During the same months reflectivity of the Moscow sample did not decrease at all.

Since decrease of reflectance of silver roughly indicates the presence of sulfide gases, it can be concluded that the atmosphere in the Lewiston-Clarkston area has a much greater concentration of these gases than does that in Lewiston Orchards and Moscow. The high tarnishing rate in Lewiston seems to indicate that this city is closer to the source of sulfide gases than is Clarkston. Proximity to a source, as

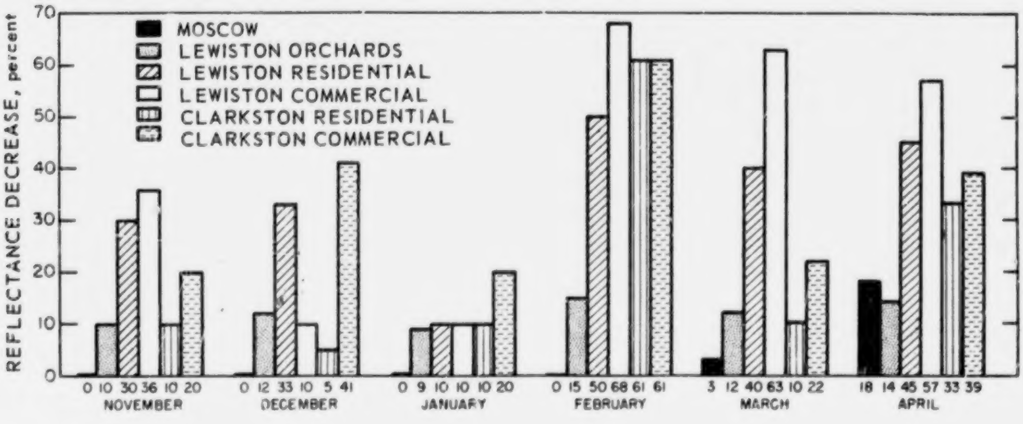

Figure 5-3. Monthly tarnishing of silver samples by station.

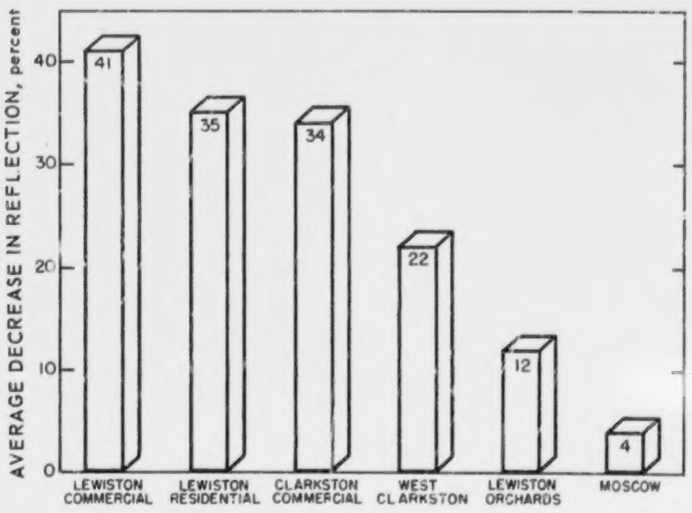

Figure 5-4. Average silver tarnishing by station for 6-month study period

well as a downwind location, would lead to a high tarnishing rate, as is the case in Lewiston. The pulp mill is the only major source of sulfide gases in the Lewiston-Clarkston area (see the emission inventory, Chapter III), which leads to the conclusion that its emission are the cause of the rapid tarnishing observed. Silver tarnishing indicates a condition that might also produce accelerated corrosion in a variety of other materials, notably iron and steel.

PAINT BLACKENING

In areas of industrial activity paint blackening is not uncommon.[7] In communities throughout the United States, exterior house paint is blackened, sometimes in whole areas during a particularly bad episode. The type of paint that is normally discolored contains white lead or some other lead compound. The lead reacts to certain gases in the air, notably H_2S and under proper conditions, forms a black compound, lead sulfide.

Two factors contribute to paint blackening. First is the fact that many painters and houseowners believe that lead pigments are necessary to make a good paint. Second is the presence of H_2S in the air. The development of new paints, which do not use lead compounds as pigments, has alleviated the problem for most areas. The possibility of using lead-base paint as an indicator for H_2S was of interest, however, so paint studies were made.

The formation of lead sulfide in lead-base paints depends on several factors in addition to the presence of H_2S in the air. An investigation by the Pittsburgh Club of the Federation of Paint and Varnish Production Clubs [8] resulted in the following conclusions:

1. With H_2S in the atmosphere, no blackening occurs unless the paint contains lead pigments.

2. The type of white-lead pigment in the paint is immaterial. The degree of blackening varies directly with lead metal content.

3. Practically no blackening occurs unless the paint film is actually wet with water, regardless of humidity.

4. The concentration of H_2S in the atmosphere appears not to be critical. Small concentrations produce blackening under optimum conditions at slower rates than large concentrations.

5. H_2S blackening is considerably delayed if the paint film is glossy and unweathered. Paint formulations high in polyvinylchloride, therefore, darken more readily since less protective vehicle is present.

Procedure

Dutch Boy white lead-base paint (95% white lead in a linseed oil vehicle) was applied to 3- by 3- by 1/4-inch stainless steel coupons with a laboratory coating rod that produced a thin film of paint. After the first coat had set, the coupon was coated on the other side. The paint was allowed to dry for 2 days before reflectance readings were taken.

Reflectance measurements were made with the same basic unit used for silver reflectance. The search unit uses a light beam normal (perpendicular) to the paint surface and a circular photocell to measure the light reflected from the paint surface at an angle of 45 degrees.

A reference paint sample was used to standardize the instrument, and the reflectance of each sample was determined at several points on the panel (there was some variation in the paint thickness). The average reflectance reading was recorded for each panel.

The samples were exposed in the following manner: Eight paint panels were attached to the exterior walls of each of six sampling stations, so that two panels faced north, two south, two west, and two east. One panel on each wall was placed in a protected position, e.g., under the eaves of the roof, where rain would not wet it. The other panel was placed in a position exposed to sun, wind, and rain.

Results

The results obtained from the paint samples were inconclusive. The samples in the exposed mountings suffered greater decrease in reflectance than did the corresponding protected sample in 13 cases. Conversely, the protected samples suffered a higher decrease of reflectance in 11 cases (Table 5-2). There was no observable damage from H_2S; therefore, the loss of reflectivity may be attributed to weathering and soiling.

Results of chemical analysis of several paint samples show that no lead sulfide was detectable in the paint. This adds credence to the conclusion that H_2S damage did not cause reflectivity loss.

H_2S was detected in the area by analysis of air samples, silver tarnishing, and AISI sampler tapes. The failure of the paint to respond to the H_2S may be attributed to two factors. First, the paint used in the study had a high gloss that would make it resistant to sulfide damage. The assumption that sufficient weathering would take place over the study period to make the paint reactive was not valid. Examination of the samples at the end of the study revealed that the surface was still glossy, and apparently little weathering had occurred. Second, the samples were exposed "dry" and this retarded the formation of lead sulfide, as has been shown in experiments.[8] Admittedly, fog and dew may contribute to the formation of a water film on the paint surface, but to what extent is unknown.

Conclusions Regarding Paint Blackening

The results of the paint study may be regarded as inconclusive. It would seem that future studies might profit from this experience. Some method of keeping the paint covered by a film of water must be devised. The blanks should be weathered artificially or in an area free of H_2S to overcome the glossiness of the paint surface. A long-term comparison of "leaded" versus "nonleaded" paints should be made.

HEALTH AND WELFARE IMPLICATIONS

Adverse effects from ambient atmospheres polluted with mixtures of various substances have been well documented, but unfortunately, many specific industrial sources of pollutants, including the pulp and paper industry, have not been adequately studied. Such information is only now being collected and reported. Preliminary data from a recent health survey of a community whose air was contaminated by stack discharges from a pulp and paper mill seemed to indicate that the pollutants may have been associated with nonspecific respiratory tract irritation.

Our lack of more precise data does not, however, leave us devoid of any data from which we can deduce some reasonable and useful conclusions. We know the effects upon health and well-being of some of

Table 5-2. RATE OF PAINT DARKENING BY AREA FOR STUDY PERIOD

Sampling station	Direction of exposure	Decrease in reflectance, %	
		Exposed mounting	Unexposed mounting
Moscow control 1	North	13	14
	South	16	23
	East	3	16
	West	18	3
	Average	13	14
Lewiston Orchards 2	North	7	3
	South	7	6
	East	3	5
	West	7	4
	Average	6	5
Lewiston residential 3	North	9	0
	South	9	7
	East	7	6
	West	0	6
	Average	6	5
Lewiston commercial 4	North	10	3
	South	14	2
	East	23	13
	West	11	7
	Average	15	6
West Clarkston 5	North	6	9
	South	11	7
	East	4	7
	West	7	10
	Average	7	8
Clarkston commercial 6	North	8	11
	South	8	16
	East	7	13
	West	7	4
	Average	8	11
Clarkston commercial titanium dioxide paint 6S	North	5	
	South	7	
	East	5	
	West	5	
	Average	6	

the individual noxious materials discharged into the air from pulp and paper plants. Presented here are the effects of hydrogen sulfide (and the organic sulfides) and nonspecific carbonaceous material contained in black smoke. [9-13]

The sulfides of hydrogen (and the organic sulfides) have a rather offensive odor, even in very small concentrations. At greater concentrations - unlikely in the ambient air from industrial processes - the sulfides irritate exposed membraneous surfaces, causing excessive tearing and dry cough. The concentrations one may expect in the air generally cause a nuisance by virtue of their disagreeable odors, which can lead to nausea and vomiting.

The carbonaceous material contained in black smoke can be expected to act primarily as an irritant, causing sneezes and coughs. Nothing more definite is known about the smoke, since its exact chemical composition is so variable.

Before this study began, it was decided that an investigation should be made of the potential (and, possibly, actual) health effects locally. For this purpose, a preliminary evaluation was made by an experienced air pollution physician who obtained information through interviews with a large segment of the local practicing physicians. Despite the difficulties and uncertainties in this type of "data" collection, it was believed that the following summarizing statements could reasonably be made:

1. Fifty percent of the physicians practicing in Lewiston and Clarkston were interviewed. Several had been practicing for more than 10 years in the area. A large majority of the physicians stated that they concurred in their patients' belief that certain of their disease conditions were related to air pollution.

2. Three of the 17 physicians interviewed believed that the air pollution problem was more of a nuisance than a health problem. The remainder attributed to air pollution varying degrees of effects ranging from aggravation of existing conditions to causation of specific illnesses.

3. Several physicians noted improvement in patients with respiratory conditions when the patients moved from the area of high pollution or used other means of reducing pollution exposure (air conditioning).

This information, although subjective in nature, is based on observations by experienced local physicians. Although it provides no specific evaluation of the extent or nature of the effects on health in the communities, it is consistent with information developed by objective means elsewhere.

On the basis of this information it is not possible to conclude that serious health effects in this area can be associated with the air pollution levels noted in this report. With the background of expert opinion of physicians in the area and with information from other studies, however, it can be concluded that, to avoid the possibility of adverse health effects, levels of contamination of sulfides and smoke must be reduced.

Nuisances may adversely affect human well-being. Although extremely difficult to quantify and assess objectively, there should be a wide community concern, since they are inimical to the general community welfare. In so highly subjective an area, it is not possible to provide clear guidelines on which to base reduction of air pollutants that lead to such nuisances, but as in the problem of ensuring adequate health protection, the reduction of contamination to levels below those that cause reduced visibility, soiling, other materials damage, irritation, and offensive odors would substantially reduce the likelihood of difficulty.

In conclusion, it is probably safe to assume that reduction of pollutants to levels below those that may result in nuisance effects would provide a reasonable margin of safety for human health.

SUMMARY

Silver plates exposed to the atmosphere in the control station at Moscow showed little tarnishing. In the valley locations, silver plates suffered greater tarnishing than those in the upland sites. Tarnishing of new plates was greatest during the first 30 days of exposure. During December and January lower levels of tarnishing corresponded to lower levels of pollution. Tarnishing, as an indicator of sulfide gases in the air, was greater in Lewiston than in Clarkston.

Data obtained from exposed paint panels were inconclusive. This was attributed to the durability of the glossy paint employed and to the lack of a film of moisture on the exposed surface.

Studies to provide precise data relating to health effects and pollutant concentrations were not made. Information obtained through interviews of local physicians revealed that many believed local air pollution was adversely affecting some of the townspeople.

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CHAPTER VI. PUBLIC AWARENESS AND CONCERN WITH AIR POLLUTION *

INTRODUCTION

In its report, "National Goals in Air Pollution Research," the Surgeon General's Task Group states: "The aspects of air pollution which are most apparent and of greatest personal concern to the individual probably are irritation to the eyes, nose, and throat, malodors, and the reduction of visibility. The pollutants responsible for these effects are undesirable whether or not they cause long-range health effects or economic losses, because they constitute an annoyance to people."

Since aerometric study by itself cannot disclose the extent of this annoyance to people, a survey of public awareness of and concern with air pollution was conducted in Clarkston.

Included in this survey were approximately 100 randomly selected heads of Clarkston households or their spouses - persons who bear the major share of responsibility for making and maintaining a residence in the community. Specially trained interviewers, using a questionnaire developed for this study, visited each member of the sample in his or her home between May 20 and 25, 1962, to gather data. To avoid premature focus on air pollution, interviewers defined the survey situation as one concerned with "certain health conditions in Clarkston."

Survey results disclose, first, that 81 of the 104 respondents believe a condition of air pollution does exist "at some time during the year" in Clarkston. Furthermore, in reply to the question, "What do you think the words air pollution mean to most people in the area?" 91 percent of the 104 respondents indicated they thought it was some form of malodor; 74 percent, low visibility; 62 percent, frequent nose or throat irritation; and 40 percent, frequent eye irritation. In contrast, only 27 percent thought that air pollution meant too much dust and dirt in the air.

Against this background of widespread public awareness of the existence of air pollution, the survey considered next the degrees to which atmospheric pollution gave rise to feelings of annoyance or concern. Spontaneous expressions of annoyance furnish one type of evidence of this concern. Interviewers asked at the start of their visit, "Are there some things you don't like about living in Clarkston? If so, what?" About 33 percent (34) of the respondents listed spontaneously a disadvantage explicitly related to air pollution. Of these, 23 respondents referred to malodors (e.g., "smells," "bad smells," "stinks"); 4, low visibility (e.g., "haze," "smog," "smoke"); 5 some unspecified aspect of air pollution (e.g., "bad" or "poor" air); and 2 listed multiple aspects of air pollution.

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* See complete report, PUBLIC AWARENESS AND CONCERN WITH AIR POLLUTION: CLARKSTON, WASHINGTON - MAY 1962. To be published by the Division of Air Pollution, Public Health Service.

A second index of concern or annoyance with air pollution appears in the fact that about 66 percent of the sample said they were bothered "somewhat" or "quite a lot" by air pollution over the city — a percentage identical to that found among Los Angeles residents in 1956.

A third indication of concern or annoyance is that 7 out of every 10 respondents (70 percent) called air pollution a "serious" or "somewhat serious" problem for their community. By contrast, in the spring of 1962, only 45 percent of Buffalo residents rated air pollution a "serious" problem for their city in answer to a similar survey question.

As indicators of the trend of public annoyance or concern with air pollution in Clarkston, the survey found that about 66 percent of those who regarded air pollution as a "serious" or "somewhat serious" community problem said that it either had been so continuously or was becoming a more serious problem each year.

SOURCES OF AIR POLLUTION

Although Clarkston residents differ in the degree to which they express annoyance or concern with air pollution, the survey revealed that they show virtual unanimity in defining as its prime source the kraft paper mill. Three lines of evidence support this conclusion.

First, of the respondents who spontaneously mentioned air pollution as a Clarkston disadvantage and who specified a source, all mentioned "the mill" and only the mill as point of origin. A typical response to the question, "Are there some things you don't like about living in Clarkston?" was: "The smell of the pulp mill."

Second, 26 of 33 respondents who had been living in Clarkston since 1950 or before and who said air pollution existed in Clarkston at present answered the question "When did you first notice air pollution in Clarkston?" by saying "When the mill started." Four gave a date between 1951 and the present; only two gave a date in 1950 or before; one said he did not remember.

Third, in answer to the question, "What do you think are the major sources of air pollution in this area?" (Item 15 in the questionnaire form), 92 percent (75 respondents) of the respondents who showed awareness of air pollution named "the mill" first. Two persons said "automotive vehicles," one person, "the dump," and one person, "the stockyard."

ACTION TO REDUCE AIR POLLUTION IN CLARKSTON

From the foregoing sections emerges the outline of a problem situation disturbing in some degree to 7 out of 10 Clarkston residents in the survey, namely, the problem of air pollution conceived as malodor, a problem attributed almost universally by those residents to the kraft paper mill. To explore the potential for action to ameliorate the air pollution among Clarkston residents, the survey attempted first to discover the extent to which they believed the problem could be alleviated. For this reason interviewers asked (Item 14): "Do you believe that air pollution in Clarkston . . .

1. Cannot be reduced below its present level,
2. Can be reduced below its present level,
3. Can be almost completely eliminated?"

Replies to this item show that only 4 percent of the subjects who believed air pollution existed in Clarkston (81 replies) took the position that it could not be further reduced, whereas 14 percent said they did not know. By contrast, 58 percent believed air pollution could be reduced below its present level, and 21 percent believed it could be almost completely eliminated in Clarkston.

Next, interviewers asked respondents, "Which one of these statements do you think best describes the effort (each of the pollution sources respondent mentioned) is making to control air pollution in this area?" With only figures for the kraft paper mill considered, nearly 75 percent of those who listed it as a pollution source said to varying degrees that "it was not doing as much as it should" to control air pollution in Clarkston.

These two sets of data lead to the inference that a relatively high potential for situation-altering actions exists in Clarkston with reference to the air pollution problem. Eighty percent of respondents who recognize the existence of the problem say it can be ameliorated; 75 percent of those who consider the pulp mill as principal source of the problem say it is not doing as much as it should towards this amelioration.

CONCERN WITH AIR POLLUTION IN RELATION TO DEMOGRAPHIC AND SOCIAL CHARACTERISTICS OF CLARKSTON RESIDENTS

Previous studies have documented an ecological component — area of residence — in levels of exposure to different types of ambient air pollution, and by extension, to degrees of concern with air pollution as a personal and community problem. A north-south division seemed likely to provide some differences in residential exposure to and concern with pollutants in Clarkston. Sycamore Street, extended to 15th, was used as boundary between the northern and southern halves of the city.

The first and major finding, from responses of sample participants in these two sectors, is that they show no difference in recognition of the existence of air pollution or concern with it as a problem. A specially devised composite scale was used for indications of concern. On the other hand, other factors show marked relationship to the degree of concern with air pollution manifested; these are occupation of household head and length of residence in the community. Approximately 66 percent of persons interviewed who had been living in Clarkston since 1950 or before were "highly concerned" with air pollution as a problem, compared to a little over 33 percent of those who had moved to the city in 1951 or later. Independent of length of residence, respondents from households whose heads are professionals, proprietors, or managers expressed the most concern with air pollution; those from households whose heads are semiskilled or unskilled workers expressed the least concern; and those from clerical and skilled-craft occupational backgrounds expressed concern in the middle range. These findings may be interpreted to mean that increasing length of exposure to what is defined as noxious environmental conditions produces increasing exacerbation rather than habituation to it. They also indicate that air pollution in Clarkston constitutes a community-wide problem. From a sociological point of view, the survey finds that the more persons are involved or identified with the community, the more they tend to be concerned with air pollution as a community problem. In other words, concern with air pollution in Clarkston apparently does not stem from, lead to, or express itself with generalized negative feelings or rejection of the community as a place to live; on the contrary, such concern appears to grow out of widespread feelings of civic pride, which results in a desire to ameliorate the situation. Of respondents 85 percent rate Clarkston an excellent or good place to live despite the fact that 70 percent said that air pollution was a "serious" or "somewhat serious" problem for their community.

From the methodological standpoint of research on enviornmental health problems, this study may be of interest in that it took place under circumstances that dramatize the independence of psychosocial variables, awareness of environmental pollution, and definition of such pollution as an individual or social problem from physically defined levels of pollution. The physical level of air pollution in Clarkston appears to be roughly constant for people according to area of residence, and yet, phenomenal awareness of and concern with air pollution as a problem vary markedly among socially defined subgroups.

Awareness or definition of pollution as a problem, in a society, cannot, therefore, be regarded as a simple direct function of the society's capacity to produce pollution. Indeed, some of the same social factors that induce high capacity to pollute the air may lead to low awareness of air pollution as a social problem.

Conversely, a situation is entirely conceivable in which an increasing concern with air pollution as a social problem may be manifest in the very same place where and in the very same period when physical levels of pollution are decreasing. In fact, this may well be the situation in Clarkston. No grounds are known for doubting the statements of officials of the kraft mill that they have taken measures to reduce substantially the quantity of odor-bearing effluent from the mill in the period 1951 to May 1962; yet in May 1962, 52 percent of respondents to the present survey said air pollution as malodor had either remained unchanged over these years as a serious problem for Clarkston or had increased in gravity.

Examples of this kind illustrate the need for a broad research attack on the relationship between the social- and physical-system dynamics of man in community. "If men define situations as real they will be real in their consequences." The reality of the Clarkston residents' definition of their air environment is evidently no simple function of the reality of that environment as defined aerometrically. From increased understanding of the independence and interdependence of these two orders of reality may come progress in achieving the goals of environmental health.

SUMMARY

The survey of public opinion concerning air pollution showed that approximately 80 percent of the persons interviewed believed that Clarkston had an air pollution problem. About 66 percent indicated they were bothered by it. Bad smells, frequent haze or smog, nose and throat irritation, eye irritation, and excessive dust and dirt were cited as the principal air pollution phenomena. More than 90 percent (75) of the respondents who reported they were aware of air pollution named the pulp mill as responsible. More than 33 percent believed official enactment of air pollution control measures is needed. Air pollution in Clarkston appears to constitute a community-wide problem. Concern appears to be associated with civic pride and a desire to ameliorate the situation. Documentation of these data is set forth in the complete report.

CHAPTER VII. APPRAISAL AND SOLUTION

GENERAL

Data and information obtained during this 6-month study indicate that the cities of Lewiston and Clarkston have air pollution problems of sufficient magnitude to warrant immediate initiation of a program of action to improve and conserve air quality. Orderly community development requires a program of air resources management equal, at least in the interest and effort applied, to the planning programs for utilization and control of land and water resources.

The ability of the atmosphere in the Lewiston-Clarkston valley to cleanse itself has been exceeded on many occasions during periods of atmospheric stagnation characterized by unusually low wind speeds and persistent atmospheric temperature inversions. The result has been an accumulation and concentration of pollutants in quantities sufficient to affect the welfare of residents of the area adversely.

Prior to this study, complaints about bad odors and visibility reduction had indicated a growing public consensus that something was wrong with the air in Lewiston-Clarkston and that something had to be done to correct the situation. Episodes of damage to house paint coupled with rapid tarnishing of silver had reinforced the opinion that conditions were deteriorating.

Health effects were not investigated in detail. Sufficient information was obtained, however, to indicate a certain degree of apprehension about harmful effects of air pollution. Specifically, some of the physicians in the area have pointed out a need for medical studies of the effects of air pollution on health of residents of the communities. Medical studies of susceptible persons would provide sufficient information to judge whether or not an actual health problem existed. The extent and severity of any actual problem would necessarily be part of this health study.

The need for air pollution control by the communities and their industries is implicit in the apprehension apparent in the pressures exercised by the afflicted citizenry who motivated the request for assistance from the Mayor of Clarkston to the Public Health Service. This concern is also revealed in the public opinion survey. Public concern and awareness are important measures of an air pollution problem, since they reflect the importance the public attaches to it. 1 In the minds of the people of this area, an air pollution problem does exist. The events leading to this study are a part of the public's desire for improved utilization and management of the air resources of the communities. On this basis alone, it is the responsibility of officials of the two communities and the respective states to take joint action to achieve and maintain air quality in keeping with the needs and desires of the people of the area.

EVALUATION

Meteorologically and topographically the Lewiston-Clarkston area is unique in the annals of air pollution technology, and the factors that make the area unique are the very ones that tend to aggravate the air pollution problem. The valley formation, particularly the rapidly rising northerly slope, confines pollutants. An unusual frequency of low wind speeds and a high frequency of low-level inversions provide additional conditions conducive to pollutant accumulation. Blackening of house paint by hydrogen sulfide on several reported occasions resulted from simultaneous occurrences of environmental factors unfavorable for dispersal of pollutants. Apparently, the time interval needed for such incidents can be relatively short. Low wind speeds, combined with the predominant east-west direction of wind flow, provide another mechanism whereby pollution originating in either city can contaminate the other, which, in turn, creates a multijurisdictional problem that complicates control efforts.

Meteorological data obtained at the airport station do not provide the information necessary for interpretation and understanding of air pollution conditions in the valley. As was demonstrated in this study, this information is best obtained from a data-collecting system at the Post Office in Lewiston. This also permits use of some 30 to 40 years of past weather records obtained in the original Weather Bureau Station in the Post Office. Because of the unique meteorological factors, a weather station in the valley is a necessary part of the proposed air pollution control program.

Atmospheric concentrations of particulate and gaseous pollutants, with the exception of sulfur dioxide, generally approached indices indicative of "dirty" conditions. The data point to air pollution problems of moderate proportions that require remedial attention by the community. The average suspended-particulate concentrations were generally large.[2,3] Suspended particulates and other pollutants in combination with environmental conditions had a marked deleterious effect on air quality. For example, the number of periods with reduced visibility in the valley has increased in recent years. Since these occur most frequently during periods of high humidity, low-level inversions, and easterly winds, pulp mill emissions, particularly water vapor and particulates, are implicated as responsible for adverse conditions in the valley. To effect improvement, the community must reduce and eliminate, wherever possible and practicable, smoke emissions from all sources as well as water vapor emissions. For instance, uncontrolled and open burning of trash and garbage — both industrial and private — in public dumps and back yards usually constitutes unnecessary and avoidable air pollution. Unfortunately, in the absence of factual information, the public tends to attribute blame for such pollution to industry exclusively. Sulfides, particularly hydrogen sulfide, and other odoriferous gases emitted by the mill create a general nuisance condition in the valley. The concentrations measured created a nuisance and resulted in material deterioration, as was demonstrated by silver tarnishing and episodes of paint blackening. Although no data are available that precisely define the effect of hydrogen sulfide in small concentrations on human well-being, the concentrations here frequently exceed the minimum amount for odor detection.[2,4] The odor is disagreeable and causes numerous complaints. Obviously, on the basis of community reaction, air quality, with reference to odors, needs improvement.

SOLUTION TO THE PROBLEM

Anyone developing a program for conservation and management of the air resources of the Lewiston-Clarkston area, and for improvement of air quality must consider the unique characteristics of the area,

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as well as the need for joint and cooperative action by the two communities and their respective states.

The air resources management plan for a community should be designed to maintain and achieve air quality in keeping with the needs and desires of the people of the area and should be considered part of the comprehensive plan for the community. In this way, it will assume its proper role in relationship to other planning considerations such as transportation, land use, waste disposal, water supply, etc. With a proper air resources management plan, suitable air quality can be achieved in an orderly fashion and at the lowest possible cost to the community. Difficulties that might arise because of air pollution would be minimized.[1]

The method suggested for achieving satisfactory, long-range air resources planning and management involves a number of steps. It permits immediate joint action while the participating agencies plan the permanent organizational structure needed to implement a program for solution and control of the interstate problems of this air pollution basin. The approach suggested is based on agreements reached by the participating agencies in a conference held in Coeur d'Alene, Idaho, July 9 and 10, 1963. In making these recommendations, the participating agencies recognized that the protection of air resources is essential to human well-being and orderly development of the area.

THE AIR RESOURCES MANAGEMENT COUNCIL

As a first step, an Air Resources Management Council is to be organized and activated in 1964. The Council is to consist of representatives of the county, municipal, and state governments involved. The Public Health Service will act in an advisory capacity.

The Council is to act in an official capacity and is charged with the responsibility of developing plans and programs for the Regional Air Resources Management Agency. The manner, method, and time schedule for accomplishing this goal will be determined by local and state officials with the guidance of representatives of the public and of commercial and industrial interests of the area.

As a first step the Council should obtain sufficient authority from the two city governments, and their respective counties, for initiation of planning, elements of which should include activities in the following areas:

1. Surveys and studies

    a. Organization and development of an air quality monitoring network adequately financed and staffed to permit expert measurement of the concentrations of air pollutants and with sufficient legal authority to execute a sound program for air quality conservation.

b. Initiation of survey activities, particularly those concerned with the collection and analysis of air quality data. This activity would serve as a guide in defining the existing air quality and provide the basis for determining what additional data are needed.

c. Establishment of a meteorological station in the valley with sufficient instrumentation for measurement of routine meteorological parameters and for special measurements required to evaluate the influence of valley topography.

d. Evaluation of existing data on air pollution, as well as industrial and nonindustrial emissions to the air, as the basis for planning additional studies needed to define and control air pollution. Improvement and expansion of existing information on emissions from industrial sources is pertinent to this program. Provisions should be made to keep the inventory of emissions current as a guide in appraising control activities.

e. Development of a long-range program, in cooperation with the medical societies of the two counties and local physicians, for collection of information on effects of pollution on the health of people of the two communities.

f. Development of a method for utilizing the information provided by the Weather Bureau Research Program of the Division of Air Pollution, which forecasts periods of high air pollution potential. Atmospheric stagnation of the western United States is included in this program. This method should be developed in cooperation with the Weather Bureau Station at the Nez Perce Airport and the Public Health Service.

2. Air quality guides

a. Methods for conservation and improvement of air quality through control of process emissions should be developed, first by assembling information on existing practices, and second, by investigating new methods. The Council should establish voluntary technical committees whose function would be to investigate control systems and advise the council on methods of reducing emissions at a reasonable cost to the communities and industries of the area. Study and revision of existing performance standards should be included.

b. Air quality standards should be studied by the Council to determine current and future status of air pollution levels. The standards would provide a basis for determining technical studies that need to be undertaken.

c. The Council should take whatever steps appropriate and necessary to develop such standards as part of the planning activities and procedures of the communities.

3. Legislation and administration

a. The Council should initiate collection of information on programs and laws authorizing control of air pollution. * This should include investigation of methods of integrating air pollution planning with other community planning programs. The collection of information on anticipated future community developments should be part of the planning studies.

b. The Council, in developing its own organizational and administrative structure, should provide for an adequate public information program. This should include adequate explanation of control measures employed, public hearings when necessary, and periodic and annual reports on activities. It is important that the public be apprised of all efforts undertaken in the community to preserve and improve air quality.

4. Regional cooperation

This study demonstrates the complexities and difficulties that arise when air pollution afflicts a region subject to several political jurisdictions — in this case, two cities and their respective counties and states. Action by one without the cooperation of the others is productive only of failure. To effect improvement under existing divided authority is difficult. Independent legal actions by afflicted parties provide no permanent solution for the two communities.

Industrial and commercial growth of the total economic community requires cooperation of all parties, both public and private. Progress in solution of the problems of this air pollution basin involves similar cooperation.

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* See Appendix D for a review of current legal authority.

The division of responsibility among levels of government as to the control of air pollution and establishment of control standards has been described.[5]

To overcome some of the current administrative difficulties, the Public Health Service, in its advisory capacity, can provide technical assistance to the joint efforts of the communities as may be necessary and desirable during the developmental phases of this program.

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APPENDIX A. ANALYTICAL METHODS

HIGH-VOLUME SAMPLES

TOTAL SUSPENDED PARTICULATES

Total suspended particulates were collected with a high-volume sampler on a glass-fiber filter web. A single 24-hour sample was collected daily at each station. Flow rate for the samples was approximately 60 cfm. The glass-fiber filters were initially dried at 60°C and weighed. Initial and final flow rates and the total sampling time were recorded for each sample, then the filters were again dried at 60°C for 16 to 20 hours and reweighed. From the net weight gain, total sampling time, and average flow rate, the concentration of total suspended particulates was calculated and expressed in micrograms per cubic meter.

WATER-SOLUBLE SULFATES

Subsequently, the high-volume filter samples were analyzed for water-soluble sulfates, sodium and calcium metals, and heavy metals.

A 4 percent aliquot of particulate sample was refluxed for 4 hours with 35 milliliters of distilled water. The samples were filtered, washed, and cooled, and the final volume was brought to 40 milliliters. Twenty milliliters of water extract was pipetted into 25 milliliters of 95 percent glycerine-ethanol mixture (1:2 vol/vol). The solution was mixed thoroughly and the volume adjusted to 25 milliliters. Approximately 0.25 gram of barium chloride was added and thoroughly mixed to dissolve the crystals. The resulting suspension of barium sulfate precipitate was allowed to stand for 40 minutes. The percent transmission of suspension was read against a distilled-water blank at 500 millimicrons on a Spectronic "20" spectrophotometer. Sulfate concentration was taken from a standard curve. Particulate sulfates were reported in micrograms per cubic meter.

SODIUM

The remaining 20 milliliters of water extract was analyzed spectrophotometrically for sodium content. Analyses were conducted on a Beckman DU Spectrophotometer with flame photometer attachment. Emission intensity at 589 millimicrons was measured and sodium metal concentration taken from a standard curve. Particulate sodium was calculated and reported in micrograms per cubic meter.

CALCIUM

Calcium analyses were run on a nitric-acid extract of the high-volume filter. A 2 percent aliquot of the filter was refluxed with 15 milliliters of 20 percent HNO_3 for 4 hours. The extract was filtered and cooled, and the volume adjusted to 20 milliliters.

Calcium analysis was completed on the Beckman DU Spectrophotometer equipped with a flame photometer attachment at 422 millimicrons. A standard curve was used to give concentrations in the extract in micrograms per milliliter. Results were extrapolated, and calcium concentrations calculated in micrograms per cubic meter.

HYDROGEN SULFIDE

Hydrogen sulfide was determined in two ways: by the AISI strip filter paper sampler [1] and by the colorimetric methylene blue procedure. [2]

AISI PROCEDURE

The AISI procedure utilized lead-acetate-impregnated paper for the detection of H_2S in the air as described by Sensenbaugh and Hemson. [1] Initially the air sample was drawn through teflon tubing from the ambient air, passed through a filter to remove suspended particles, and then over a water reservoir to humidify the air stream. The air was then drawn through the impregnated tape, where H_2S reacted with the lead acetate to form lead sulfide, a black compound. After passing the vacuum pump, the air was discharged through a soda-lime tube that removed excess humidity into the enclosed face of the instrument. This procedure maintains a slight positive pressure in the enclosed case and prevents interference and darkening of the tape by the ambient air.

Air was drawn through the impregnated filter tape at a known rate, approximately 0.22 cfm, for a period of 2 hours. At the end of the sampling period, the timing switch actuated the reset mechanism, which automatically indexed the filter tape to a new position, and the sampling cycle was repeated.

Tapes were marked every 2 days to show the date and time of the sample collection, and at intervals, the exposed tapes were replaced with fresh tapes. The optical density of the black spots was determined, relative to the clean paper, with a transmissometer, and the concentration of H_2S was determined from a standard curve provided by the instrument manufacturer.

COLORIMETRIC METHOD

H_2S was determined colorimetrically by the methylene blue procedure described by Jacobs, et al. [2] A Gelman sequential sampler collected 12 samples each day in an all-glass midget impinger containing 10 milliliters of a cadmium-hydroxide-absorbing solution. Samples were collected for 115 minutes of each 2-hour period. Airflow was controlled at a rate of 2.5 liters per minute by a critical orifice in the vacuum line.

At the end of each 24-hour period, the impinger samples were taken to the laboratory with a reagent blank. To each sample, 0.5 milliliter of aminesulfuric-acid test solution and one drop of $FeCl_3$ solution were added; the sample was then mixed. The volume was adjusted to 15 milliliters with distilled water, and 30 minutes was allowed for full color development. Percent transmission of the reagent blank was set at 100, and the percent transmission of each sample was read at 670 millimicrons on a Spectronic 20 spectrophotometer with either 1/2-inch or 1-inch test tubes.

The micrograms of H_2S in each sample was read from a standard curve, and the atmospheric concentration was calculated in parts per million.

SULFIDE DAMAGE OF PAINT AND SILVER SAMPLES

The presence of H_2S and sulfur-bearing compounds in tarnished silver plates and in darkened, lead-based paints applied to metal coupons was determined by qualitative tests. A confirmatory test for the presence of sulfide was performed in the following manner: concentrated hydrochloric acid was dropped onto the surface of the exposed sample. The evolved gases were aspirated through an absorbing reagent containing a cadmium hydroxide suspension that removed any H_2S in the stream. The presence of sulfide was determined qualitatively by the methylene blue method. The formation of a blue color in the solution is confirmation of the presence of sulfide.

REFERENCES

1. Sensenbaugh, J. D. and Hemeon, W.C.L. A low-cost sampler for measurement of low concentration of H_2S. Air Repair, May 1954.

2. Jacobs, M.B., Braverman, M. M., and Hochheiser, S. Ultramicrodetermination of sulfides in air. Analytical Chemistry 29:1934.

METHOD OF TEST FOR ODOR SENSITIVITY

Three odorants were used in the November sensitivity test; vanillin, methyl salicylate (oil of winter-green), and butyric acid. The first two are pleasant, whereas the third, butyric acid, has a stench much like rancid butter.

The vanillin and methyl salicylate were diluted with benzyl benzoate; butyric acid was diluted with water. Experience showed, however, that the odor of benzyl benzoate, although slight, was sufficient to mask the methyl salicylate and confuse many observers. In the April tests the diluting medium was water, and the methyl salicylate was replaced with amyl acetate, which has the pleasant odor of banana oil.

For each odorant three dilutions were prepared, one considered to be below the normal detectable threshold, one detectable by majority of the normal population, and a third that was higher by a factor of 10 than the normally detectable level.

The solutions were prepared in the following ways.

Vanillin: One gram was dissolved in 250 milliliters water at 76°F. This gave a solution of 0.4 weight-percent. This solution was used as a stock solution for subsequent dilution to form the three test solutions, as follows:

1. First test solution: 25 milliliters of stock solution in 100 milliliters of H_2O giving 0.1 percent by weight.
2. Second test solution: 10 milliliters stock in 390 milliliters H_2O giving 0.01 percent by weight.
3. Third test solution: 1 milliliter stock in 399 milliliters H_2O giving 0.001 percent by weight.

Distilled water was used in all cases; any stock solution could be used although there is a limit to the solubility of vanillin in water.

Amyl Acetate: One-tenth gram was dissolved in 99.9 milliliters water to give a stock solution of 0.1 percent by weight.

1. First test solution was the stock solution.
2. Second test solution: 10 milliliters stock in 90 milliliters H_2O giving 0.01 percent by weight.
3. Third test solution: 1 milliliter stock in 99 milliliters H_2O giving 0.001 percent by weight.

Sufficient time and mixing must be allowed to make certain the stock solution is uniform. In the case of vanillin and amyl acetate the solution was heated to about 120°F to aid mixing.

Butyric Acid: One-tenth gram was dissolved in 99.9 milliliters water to give a stock solution of 0.1 percent by weight.

1. First test solution: 10 milliliters stock in 90 milliliters H_2O giving 0.01 percent by weight.
2. Second test solution: 1 milliliter stock in 99 milliliters H_2O giving 0.001 percent by weight.
3. Third test solution: 1 milliliter stock in 999 milliliters H_2O giving 0.0001 percent by weight.

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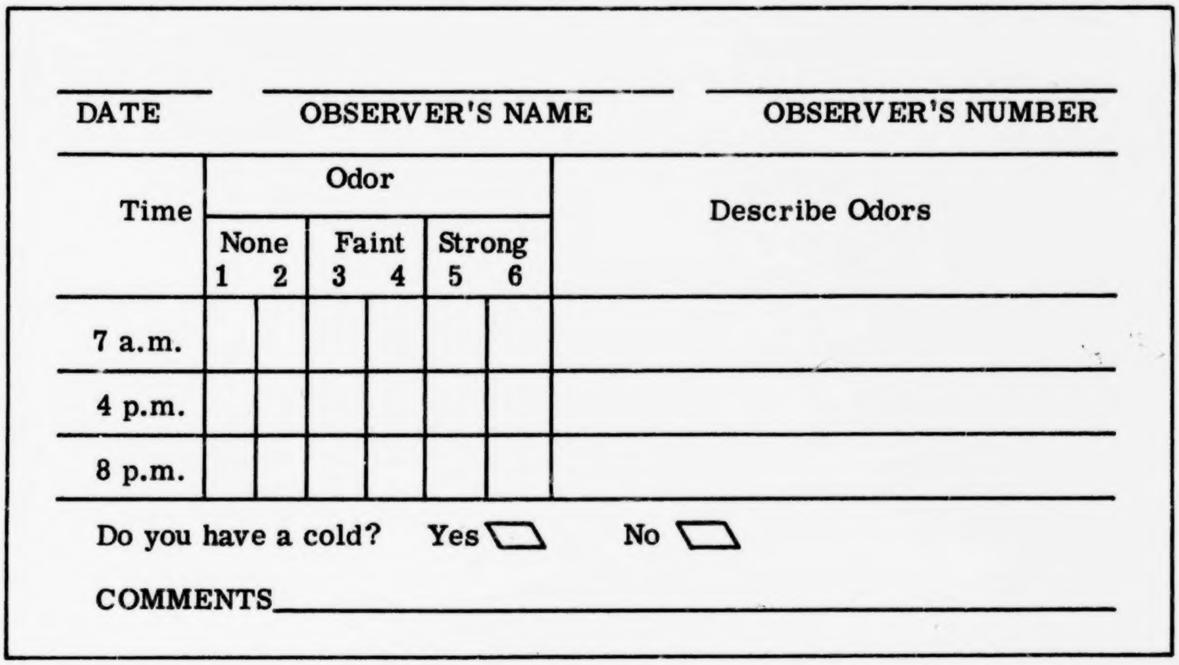
Preparation of the butyric acid solution requires the use of a hood since the odor of butyric acid is very objectionable.

Each odorant was placed in an odor triangle with two blanks. The position of the odorant in the triangle was changed from group to group. Each vial was numbered and the observers recorded the number of the odorous vial in each group. The observers were cautioned that some groups might have no odorous material at all, though a set of blanks was included only in the April test.

The observers were asked to refrain from smoking for 1/2 hour before the test. Questionnaires were used to obtain name, grade, and residence location. The students were asked to note whether they had a head cold and if so, to indicate how severe it was. Each test group was limited to 20 persons to facilitate supervision.

Each observer was instructed to bend over the vial and "sniff" sharply. The necessity for "sniffing" is a result of the location of the odor-sensing organ in the nose; normally inspired air does not come in contact with this organ. When turbulence is induced by a sudden inspiration of air - "sniffing" the air is brought into contact with the sensitive membranes. Observers were asked to wait a few seconds between each triangle to allow any possible effects of fatigue to diminish.



DATE ______ OBSERVER'S NAME ______ OBSERVER'S NUMBER ______

Time	Odor						Describe Odors
	None		Faint		Strong		
	1	2	3	4	5	6	
7 a.m.							
4 p.m.							
8 p.m.							

Do you have a cold? Yes ☐ No ☐

COMMENTS______

Figure A-1. Facsimile of odor observation card.

APPENDIX B. CORRESPONDENCE

LETTER FROM CITY OF CLARKSTON TO THE DIVISION OF AIR POLLUTION, PUBLIC HEALTH SERVICE, NOVEMBER 4, 1960.

The Mayor of Clarkston, Washington, asked for assistance in a local air pollution problem that was, for reasons explained in the letter, too big to be handled at either a local or state level. The Mayor cited information describing air pollution problems and their effects on the 12,000 residents of the City of Clarkston. He pointed out that the pollution originated near the City of Lewiston, a city of 25,000 inhabitants, in the State of Idaho. The Mayor referred to potential health effects and submitted two exhibits to show environmental deterioration and property damage. A third exhibit described the unique climatology and topography of the region comprising Lewiston and Clarkston. The Mayor emphasized that pollution originated in the adjacent State of Idaho and that attempts to secure remedial action had not been productive.

LETTER FROM THE DIVISION OF AIR POLLUTION, PUBLIC HEALTH SERVICE, TO THE CITY OF CLARKSTON, NOVEMBER 15, 1960.

The Chief of the Division of Air Pollution, in reply to the Mayor's letter, pointed out that the federal government had no regulatory authority for control of air pollution and that existing legislation specifically stated that it was the intention of Congress that such authority should rest with state and local governments. He stated that because of the interstate character of the problem the Division of Air Pollution would explore with the appropriate state authorities their understanding of this problem and propose solutions. Furthermore, he indicated that the Public Health Service's regional representative would be instructed to initiate appropriate action.

LETTER TO THE IDAHO DEPARTMENT OF HEALTH FROM PUBLIC HEALTH SERVICE OFFICE, REGION VIII, NOVEMBER 23, 1960.

The Regional Medical Director, in his letter to the Administrator of Health, requested an opinion about the air pollution problem and offered the assistance of the Division of Air Pollution in further discussion of this matter.

LETTER TO THE PUBLIC HEALTH SERVICE OFFICE, REGION VIII, FROM THE IDAHO AIR POLLUTION CONTROL COMMISSION, MAY 1, 1961.

The Secretary of the Idaho Air Pollution Control Commission informed the Regional Medical Director that the Public Health Service's offer of assistance had been presented to the Commission at its regular meeting in Boise, Idaho, on February 13, 1961. The Commission accepted the offer of assistance and requested that a representative of the Division of Air Pollution attend the next meeting of the Commission, on June 5, to discuss the Public Health Service's study proposal.

LETTER TO THE DIVISION OF AIR POLLUTION FROM THE WASHINGTON STATE DEPARTMENT OF HEALTH, OCTOBER 2, 1961.

The Engineer in Charge of the Air Sanitation and Radiation Control Section of the Department of Health, State of Washington, informed the Chief of the Technical Assistance Branch, Public Health Service, that he was basically in agreement with the outline proposed for the study of air pollution in Clarkston. Furthermore, he designated a survey director for the Washington State Health Department and outlined suggestions and recommendations on various aspects of technical study.

LETTER TO THE DIVISION OF AIR POLLUTION FROM THE IDAHO AIR POLLUTION CONTROL COMMISSION, OCTOBER 3, 1961.

The Chairman of the Idaho Air Pollution Control Commission indicated to the Chief of the Technical Assistance Branch, Public Health Service, that the proposal for a study, dated August 15, was acceptable to the Commission and granted authorization to proceed with the study. Moreover, the Chairman added several recommendations to the proposal to ensure maximum objectivity.

LETTER TO THE IDAHO AIR POLLUTION CONTROL COMMISSION FROM THE DIVISION OF AIR POLLUTION, OCTOBER 11, 1961.

The Deputy Chief of the Technical Assistance Branch, Division of Air Pollution, in reply to the letter from the Idaho Air Pollution Control Commission, stated that the study would be carried out as objectively as possible and that all data would be treated in as scientific a manner as possible. Moreover, he commented on specific questions raised by the Commission. In addition, the Chairman of the Commission was invited to participate in the first program session scheduled for October 19, 1961, in Lewiston, Idaho.

APPENDIX C. STATISTICAL ANALYSIS OF STUDENT ODOR SURVEY DATA

Two basic statistical methods were used to analyze the data from the student odor survey. The first was the analysis of variance procedure, which was used when several variables were being tested for significant differences. When two variables were to be tested against one another, confidence limits of the population mean were used.

As described in Chapter IV, the data were compared by area and date, by day of survey, by time of day, by sex of respondents, by incidence of colds reported by respondents, and by odor sensitivity of the respondents. In addition results from the November and April study periods were compared.

AREA

The basic data used in the analysis of variance calculations are shown in Tables C-1 and C-2. A sample calculation for the November study by area is made to illustrate the procedure. Table C-3 shows the summations necessary for the computations.

1. Sum of squares from row means = $\frac{260.42055}{4} - \frac{(58.543)^2}{4 \times 14} = 3.90366$

2. Sum of squares from column means = $\frac{921.96943}{14} - \frac{(58.543)^2}{4 \times 14} = 4.65348$

3. Total sum of squares from within = $80.08473 - \frac{(58.543)^2}{4 \times 14} = 18.88325$

Table C-1. PULP MILL ODORS (NOVEMBER)

	Lewiston			Lewiston Orchards			Clarkston			West Clarkston		
Date	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening
7	4 [a] 0.400[b]	2 0.143	2 0.250	4 0.400	1 0.143	0 0	2 0.087	4 0.154	1 0.036	0 0	0 0.143	0 0
8	4 0.572	5 0.385	4 0.444	1 0.200	2 0.167	4 0.571	10 0.370	4 0.129	7 0.304	3 0.750	1 0.143	1 0.200
9	6 0.600	5 0.500.	2 0.667	3 0.750	2 0.222	1 0.167	9 0.500	2 0.185	2 0.100	3 0.600	1 0.143	0 0
10	3 0.750	3 0.500	3 0.600	3 0.600	1 0.500	2 0.500	11 0.524	5 0.217	11 0.785	2 0.500	0 0	0 0
11	1 1.000	3 0.429	4 1.000	0 0	0 0	0 0	9 0.643	3 0.150	4 0.333	0 0	0 0	0 0
12	6 0.667	6 0.600	5 0.715	1 0.250	1 0.167	0 0	14 0.600	8 0.348	3 0.120	2 0.667	1 0.167	1 0.200
13	5 1.000	4 0.800	2 0.500	1 1.000	0 0	2 0.400	8 0.500	3 0.130	5 0.385	1 0.500	0 0	1 0.333
14	5 0.333	2 0.667	0 0	5 0.675	1 0.200	0 0	3 0.273	5 0.278	7 0.500	0 0	1 0.333	0 0
15	0 0	1 0.200	1 0.500	0 0	1 0.333	0 0	3 0.373	5 0.208	5 0.455	2 0.667	1 0.333	4 1.000
16	0 0	3 0.500	1 0.200	3 0.750	0 0	0 0	9 0.600	6 0.316	6 0.286	1 0.333	2 0.500	0 0
17	1 0.333	1 0.333	1 0.500	0 0	0 0	0 0	5 0.455	4 0.190	8 0.471	1 0.333	0 0	2 0.667
18	1 1.000	0 0	0 0	2 0.500	0 0	0 0	4 0.667	4 0.200	4 0.308	3 1.000	1 0.333	3 0.600
19	3 0.750	2 0.222	3 0.750	6 0.857	1 0.200	1 0.200	8 0.800	6 0.333	6 0.375	2 1.000	1 0.250	1 0.250
20	3 1.000	3 1.000	1 0.333	0 0	1 0.167	2 0.500	4 0.267	4 0.267	4 0.364	0 0	1 0.200	1 0.250

[a] First entry is actual number of positive pulp mill odor responses (Type 1).

[b] Second entry is proportion of positive to total odor responses.

Table C-2. PULP MILL ODORS (APRIL)

	Lewiston			Lewiston Orchards			Clarkston			West Clarkston		
Date	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening
15	0[a] 0[b]	0 0	1 0.167	0 0	0 0	0 0	2 0.333	4 0.667	1 0.200	0 0	0 0	0 0
16	1 0.250	1 0.200	0 0	4 1.000	0 0	0 0	5 1.000	2 0.154	2 0.429	0 0	0 0	0 0
17	2 0.500	2 0.400	1 0.250	0 0	0 0	0 0	4 0.667	4 0.200	2 0.250	0 0	0 0	0 0
18	4 0.364	3 0.300	4 0.333	1 0.167	0 0	0 0	7 0.875	3 0.429	6 0.667	0 0	0 0	0 0
19	7 0.778	1 0.111	0 0	2 0.500	3 0.429	1 0.200	3 0.600	0 0	0 0	1 1.000	0 0	0 0
20	2 0.400	3 0.333	3 0.375	2 0.500	1 0.200	0 0	3 0.750	0 0	1 0.333	1 0.500	0 0	0 0
21	0 0	1 0.200	2 0.286	0 0	1 0.143	0 0	3 0.429	4 0.572	6 0.750	1 1.000	0 0	0 0
22	1 0.333	2 0.500	1 0.500	0 0	0 0	0 0	3 1.000	3 0.600	4 0.800	0 0	0 0	1 1.000
23	1 0.167	2 0.500	1 0.333	1 0.250	0 0	0 0	4 0.572	1 0.250	5 0.625	0 0	0 0	0 0
24	2 0.667	1 0.111	0 0	1 0.500	0 0	0 0	3 0.750	4 0.444	3 0.750	0 0	0 0	0 0
25	2 0.400	0 0	2 0.250	0 0	1 0.200	0 0	5 0.715	3 0.500	4 0.667	0 0	0 0	0 0
26	7 0.875	2 0.333	1 0.200	2 1.000	1 0.333	0 0	9 0.900	5 0.625	5 0.625	0 0	0 0	1 1.000
27	10 0.259	0 0	0 0	2 0.400	2 0.400	1 0.200	4 0.800	2 0.222	3 0.500	0 0	0 0	0 0
28	0 0	0 0	0 0	2 0.667	0 0	1 0.333	1 0.250	1 0.333	1 0.143	0 0	0 0	0 0

[a] First entry is actual number of positive pulp mill odor responses (Type 1).

[b] Second entry is proportion of positive to total odor responses.

Table C-3. ANALYSIS OF VARIANCE TABLE BY AREA AND DATE — NOVEMBER

Date	Lewiston	Lewiston Orchards	Clarkston	West Clarkston	Total
7	0.793	0.543	0.277	0.143	1.756
8	1.401	0.938	0.803	1.093	4.235
9	1.797	1.139	0.785	0.743	4.434
10	1.850	1.600	1.526	0.500	5.476
11	2.429	0	1.126	0	3.555
12	1.982	0.417	1.068	1.034	4.501
13	2.300	1.400	1.015	0.833	5.548
14	1.000	0.875	1.051	0.333	3.259
15	0.700	0.333	1.036	2.000	4.069
16	0.700	0.750	1.202	0.833	3.485
17	1.166	0	1.116	1.000	3.282
18	1.000	0.500	1.175	1.933	4.608
19	1.722	1.257	1.508	1.500	5.987
20	2.333	0.667	0.898	0.450	4.348
Total	21.143	10.419	14.586	12.395	58.543

4. Analysis of variance

	Sum of squares	df	Mean square
Row means	3.90366	13	0.30028
Column means	4.65348	3	1.55116
Residual	10.32611	39	0.26477
Total	18.88325	55	

$$F_r = \frac{0.30028}{0.26477} = 1.13412 \qquad F_{0.95}\ (13.39) = 1.94$$

$$F_c = \frac{1.55116}{0.26477} = 5.85852 \qquad F_{0.95}\ (3.39) = 2.91$$

There is, therefore, no significant difference for the pulp mill odor responses for the days of the November survey. There is, however, a significant difference among the areas for the proportion of pulp mill odors reported during the survey period.

The calculations for the April study are similar, and the tabulation and summations are presented in Table C-4.

The results show no significant differences among the days of the April study. Again, there is a significant variation among the four areas.

Table C-4. ANALYSIS OF VARIANCE TABLE BY AREA AND DATE — APRIL

Date	Lewiston	Lewiston Orchards	Clarkston	West Clarkston	Total
15	0.167	0	1.200	0	1.367
16	0.450	1.667	1.583	0	3.700
17	1.150	0	1.117	0	2.267
18	0.997	0.167	1.971	0	3.135
19	0.889	1.129	0.600	1.000	3.618
20	1.108	0.700	1.083	0.500	3.391
21	0.486	0.143	1.751	1.000	3.380
22	1.333	0	2.400	1.000	4.733
23	1.000	0.250	1.447	0	2.697
24	0.778	0.500	1.944	0	3.222
25	0.650	0.200	1.882	0	2.732
26	1.408	1.333	2.150	1.000	5.891
27	0.250	1.000	1.522	0	2.772
28	0	1.000	0.726	0	1.726
Total	10.666	8.089	21.376	4.500	44.631

Three other odor types were compared by areas by use of a statistical test, "Student t test," for significance. The odors were smoke and wood smoke (Type 2), burning leaves (Type 3), and rubbish and burning trash (Type 7). Table C-5 shows the essential information for the analyses. A sample calculation is carried out for the Type 7 odors during November.

In November, there were significant variations in the Type 2 and Type 3 odors by area. In April, Type 2 odors showed significant differences by area where Type 3 and Type 7 odors showed none.

TIME

To analyze pulp mill odors by time of day, the analysis of variance procedure was used. Table C-6 shows the essential information for the November and April study periods.

Table C-5. RESPONSES TO TYPE 2, 3, AND 7 ODORS – NOVEMBER AND APRIL

	Type 2 odors		Type 3 odors		Type 7 odors		Total positive responses	
	Nov.	Apr.	Nov.	Apr.	Nov.	Apr.	Nov.	Apr.
Lewiston	76	39	19	4	5	11	944	1,072
Lewiston Orchards	79	41	22	10	12	4	935	726
Clarkston	227	28	92	7	68	45	1,635	1,167
West Clarkston	41	14	8	0	12	5	289	204

Sample calculations with conclusion for Type 7 odors during December follow:

X = No. of Type 7 responses per 1,000 positive responses

Lewiston	5.3	$\Sigma x = 99.3$
Lewiston Orchards	12.8	$\Sigma x^2 = 3{,}506.6$
Clarkston	40.0	
West Clarkston	41.5	

1. $\bar{X} = \frac{\Sigma x}{n} = \frac{99.3}{4} = 24.8$

2. $(n-1)\, s^2 = \Sigma x^2 - \frac{1}{n} (\Sigma x)^2$

   $= 3{,}506.6 - 1/4\ (99.3)^2 = 13.8$

3. $s = \sqrt{s^2} = \sqrt{13.8} = 3.72$

4. $\mu = \bar{X} \pm t_{0.95} \frac{s}{\sqrt{n}} = 24.8 \pm 3.182\ \frac{3.72}{\sqrt{4}}$

   $= 24.8 \pm 5.9$

5. $18.9 \leq \mu \leq 30.7$

6. Conclusion: There is a significant difference at the 95 percent confidence level in the responses to Type 7 odors among the four areas during the November study period.

Table C-6. RESPONSE TO PULP MILL ODORS BY TIME OF DAY

November	Morning	Afternoon	Evening	Total	April	Morning	Afternoon	Evening	Total
7	0.887	0.583	0.286	1.756	15	0.333	0.667	0.367	1.367
8	1.892	0.824	1.519	4.235	16	2.250	1.021	0.429	3.700
9	2.450	1.050	0.934	4.434	17	1.167	0.600	0.500	2.267
10	2.374	1.217	1.885	5.476	18	1.406	0.729	1.000	3.135
11	1.643	0.579	1.333	3.555	19	2.878	0.540	0.200	3.618
12	2.184	1.282	1.035	4.501	20	2.150	0.533	0.708	3.391
13	3.000	0.930	1.618	5.548	21	1.429	0.915	1.036	3.380
14	1.281	1.478	0.500	3.259	22	1.333	1.100	2.300	4.733
15	1.040	1.074	1.955	4.069	23	0.989	0.750	0.958	2.697
16	1.683	1.316	0.486	3.485	24	1.917	0.555	0.750	3.222
17	1.121	0.523	1.638	3.282	25	1.115	0.700	0.917	2.732
18	3.167	0.533	0.908	4.608	26	2.775	1.291	1.825	5.891
19	3.407	1.005	1.575	5.987	27	1.450	0.622	0.700	2.772
20	1.267	1.634	1.447	4.348	28	0.917	0.333	0.476	1.726
Total	27.396	14.028	17.119	48.543	Total	22.109	10.356	12.176	44.631

The results for the analysis show that in both November and April the responses to pulp mill odors showed significant variations, with morning response greater than average and afternoon and evening responses less than average.

HUMAN VARIABLES

Sex of Respondent

Confidence limits of the population means were used to evaluate the difference in odor sensitivity between male and female respondents. The data are shown in Table C-7. The calculations are also shown for November.

Table C-7. ODOR SENSITIVITY TEST RESULTS — NOVEMBER AND APRIL

Test score	Frequency of occurrence			
	November		April	
	Male	Female	Male	Female
0	0	0	0	0
1	1	1	0	0
2	2	8	0	0
3	11	11	2	0
4	14	10	0	2
5	12	16	3	8
6	7	17	19	16
7	2	7	10	14
8	1	0	8	15
9	0	0	1	8

Sample calculation (November data)

Male

1. $\Sigma f = 50$

2. $\Sigma f\ x = 218$

3. $\Sigma f\ x^2 = 1046$

where f = number of respondents with a given test score

4. $\bar{X} = \frac{\Sigma f\ x}{\Sigma\ f} = \frac{218}{50} = 4.36$

5. $(n-1)\ s^2 = \Sigma f\ x^2 - \frac{1}{n}\ (\Sigma f\ x)^2$

$49\ s^2 = 1046 - \frac{1}{50}\ (218)^2$

$s^2 = 1.96$

$s = 1.40$

6. $\mu = \overline{X} \pm Z_{0.95}\ \frac{s}{\sqrt{n}}$

$\mu = 4.36 \pm 1.96 \frac{1.40}{\sqrt{50}}$

$\mu = 4.36 \pm 0.39$

7. $3.97 \leq \mu \leq 4.75$

Female

1. $\Sigma f = 70$

2. $\Sigma f\ x = 321$

3. $\Sigma f\ x^2 = 1647$

4. $\overline{X} = \frac{\Sigma f\ x}{\Sigma f}$

$\overline{X} = \frac{321}{70}$

$\overline{X} = 4.59$

Since the average odor sensitivity for females falls within the range of the male odor sensitivity no statistically significant difference was apparent for the sexes during the November study period. The same conclusion follows an analysis of the April sensitivity test results.

Incident of Colds

The same procedure as above was used in analyzing the effect of the incidence of colds in the respondents. The results show that colds had no significant effect on the odor sensitivity of the respondents for either study period. The pertinent data are shown in Table C-8.

Table C-8. FREQUENCY OF COLDS VERSUS ODOR SENSITIVITY TEST SCORE — APRIL

Test score	Cold	No cold
0	0	0
1	0	0
2	0	0
3	1	2
4	0	2
5	5	7
6	10	31
7	3	24
8	5	20
9	2	10
10	0	1

APPENDIX D. LEGAL BASIS FOR AIR POLLUTION CONTROL

This portion of the report considers the legal remedies available to public authorities to cope with air pollution problems arising in the States of Idaho and Washington, particularly the Lewiston-Clarkston area.

IDAHO

SPECIFIC LEGISLATION TO CONTROL AIR POLLUTION

Under the Idaho Air Pollution Control Act of 1959 the Air Pollution Control Commission has authority to abate air pollution (Sec. 39-2908 Idaho Code). Although the Act authorizes the Commission to adopt rules and regulations to control and prohibit air pollution throughout the State or in affected areas of the State, the Commission has received no appropriations (except small sums for travel) since its creation, and to date no action has been taken by the Commission to implement its authority.

"Air Pollution" is defined in the Idaho Air Pollution Control Act of 1959 as "the presence in the outdoor atmosphere of substances put there by man in concentration sufficient to cause an unreasonable interference with human, plant or animal life, or the reasonable use of property." (Sec. 39-2902 I.C.).

Neither the Idaho Air Pollution Control Act of 1959 nor regulations adopted pursuant to it affect ordinances or regulations adpoted by any municipality, county, or board of health where such local ordinances are not inconsistent with the Act and regulations thereunder (Sec. 39-2922, Idaho Code).

Existing civil and criminal remedies for actions that may also violate rules or regulations under the Act are preserved, and functions vested in the State Board of Health by other legislative Acts are not affected (Sec. 39-2921, Idaho Code).

The following sections of the Idaho Code relate to the control of public nuisances:

(1) Sec. 18-5901. "Public nuisance defined--Anything which is injurious to health, or is indecent, or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property by an entire community or neighborhood, or by any considerable number of persons, or unlawfully obstructs the free passage or use, in the customary manner, of any navigable lake, or river, stream, canal or basin, or of any public park, square, street or highway, is a public nuisance." (See also Sec. 52-101, I.C.)

(2) Sec. 18-5903. "Punishment for nuisance.--Any person who maintains or commits any public nuisance the punishment for which is not otherwise prescribed, or who wilfully omits to perform any legal duty relating to the removal of a public nuisance, is guilty of a misdemeanor."

(3) Sec. 52-202. "Remedies--The remedies against a public nuisance are:

    (i) Indictment or information
    (ii) A civil action, or
    (iii) Abatement."

(4) Sec. 52-205. "Abatement by public body or officer--A public nuisance may be abated by any public body or officer authorized thereto by law."

The foregoing statutory provisions appear to authorize action to abate air pollution that constitutes a public nuisance by (1) municipal authorities (Calvin v. Appleby, 78 Idaho 457, 305 P. 2d 309; Boise City v. Sinsel, 72 Idaho 145, 190 P. 2d 681) and (2) and County Board of Health of the County in which the nuisance occurs (Sec. 39-303 Idaho Code).

Under other provisions of the Idaho Code (Sec. 39-101 (14), Sec. 39-101, (13(a)) the Idaho State Board of Health appears to be authorized to abate public nuisances.

CITY CHARTER PROVISIONS - LEWISTON, IDAHO

The following provisions of the City of Lewiston Charter (Idaho Sess. Laws 1907, H.B. No. 121, p. 349) relate to the control of nuisances and dense smoke.

1. Section 86 authorizes the City Council "to declare, prevent and abate nuisances on public or private property, and the causes thereof."

2. Under Section 102, the City Council is authorized "To control, regulate and prohibit the emission of dense smoke from chimneys and chimney stacks of buildings, manufactories, locomotives, or engines within the city; and to regulate, control, prohibit, and prevent the emission of dense smoke in any manner in said city."

Under these state law provisions and provisions of the City of Lewiston Charter, authority exists for the City to take action to abate air pollution that originates within the City and constitutes a public nuisance or consists of dense smoke.

Under Idaho law, a municipality also may sue to enjoin a public nuisance originating outside of its jurisdiction - Village of American Falls v. West (Idaho 1914) 142 Pac. 42.

WASHINGTON

Specific Legislation to Control Air Pollution

The Washington Air Pollution Control Act of 1957 (Sec. 70.94.010, R.C.W.) gives cities, towns, and counties authority to adopt and enforce air pollution control ordinances after a public hearing and a resolution by the governing body declaring the necessity for controlling air pollution (Sec. 70.94.050, R.C.W.).

"Air Pollution" is defined as "the presence in the outdoor atmosphere of substances put there by man in concentration sufficient to cause an unreasonable interference with the comfort, safety or health of man; or the reasonable use and enjoyment of his property." (Sec. 70.94.030, R.C.W.)

Clarkston has not yet acted under this grant of authority.

The following provisions of the Washington Code relate to the control of public nuisances:

A public nuisance is an offense against the state (Sec. 9.66.010, R.C.W.) and is punishable by a fine of not more than $1,000 (Sec. 7.48. 250). Remedies against a public nuisance are "indictment or information, civil action or abatement." (Sec. 7.48.200.) A public nuisance may be abated by a public body or officer thereto authorized by law (Sec. 7.48.200). The county health officer has authority to abate any public nuisance within his geographical jurisdiction (Sec. 70.06.03, R.C.W.).

City Ordinance - Clarkston, Washington

The City of Clarkston Zoning Ordinance, effective April 28, 1956, establishes performance standards for permitted uses in the C (commercial) zone (Sec. 1.20.021). These standards, in essence, prohibit emissions of (1) air contaminants as dark or darker than No. 2 Ringelmann or air contaminants of equal or greater opacity (2) particulate matter or dust in excess of 0.3 grain per cubic foot, (3) obnoxious odors, (4) sulfur dioxide and hydrogen sulfide in excess of 0.5 ppm, and nitrous fumes in excess of 5 ppm, and (5) any material that in substance causes a public nuisance.

Substantially similar standards are established for the M (manufacturing) zone (Section 1.21.020).

Legal proceedings by a municipality, a county, or state to abate air pollution whose source is in another state is not wholly without precedent - Georgia v. Tennessee Copper Co. (1907) 201 U.S.230, 27 S.Ct. 618. Although such an action by a municipality, county, or state affected by a nuisance may be viewed as a possibility, however, no assurance can be given that an ultimate successful conclusion can be reached.

FEDERAL CLEAN AIR ACT OF DECEMBER 17, 1963

Section 5 of the Federal Clean Air Act (P.L. 88-206) enacted December 17,1963, provides that in the case of air pollution that is alleged to endanger the health or welfare of persons in a state other than that in which the discharge originates a conference of the air pollution control agencies involved shall be called by the Secretary of Health, Education, and Welfare at the request of the governor of any state, a state air pollution control agency, or (with the concurrence of the governor and the state agency) the governing body of any municipality.

Following the conference, if effective progress is not being made toward abatement of the air pollution and the health or welfare of any persons is being endangered, the Secretary will recommend remedial action. If appropriate action is not taken within the time allowed by the Secretary (not less than 6 months) further procedures are authorized before a hearing board and ultimately the Secretary is authorized to request that the Attorney General bring a suit on behalf of the United States to secure abatement of the air pollution.

GPO 816-920—12